Deliverable 4.5

Report on technology needs in regions

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ABSTRACT	This report provides an overview of the blue bioeconomy technological needs in the different regions. Consolidating the results of BBC findings, it highlights cross-cutting needs in infrastructure, digitalisation, and innovation transfer. The analysis supports targeted policy, investment, and SME support to drive sustainable marine-based development.
KEYWORDS	Technology needs, blue bioeconomy, Technology Readiness Levels (TRLs), innovation.

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Acronyms

BBC	BlueBioClusters
SMEs	Small and Medium Enterprises
WP	Work Package
D	Deliverable
EU	European Union
TRL	Technology Readiness Level

Executive Summary

This report was prepared under Work Package 4, “Technology Mapping and Transfer”, and aim is to identify and perform an analysis of regional technological needs in the blue bioeconomy sector within the BlueBioClusters consortium. It builds on the previous mapping activities of technology providers and value chains, as well as other activities and deliverables within the project. The main objective is to deepen the understanding of regional bottlenecks, infrastructure gaps, and innovation barriers that currently hinder the development and deployment of advanced blue bio-based solutions across Europe.

The report consolidates insights gathered through a structured methodology that included surveys, regional co-creation workshops, and in-depth interviews with 25 selected companies from the different BBC countries/regions. The focus was placed on identifying concrete needs reported by early-stage and market-ready actors from a wide spectrum of sectors, including macroalgae cultivation, aquaculture engineering, marine biotechnology, circular valorisation of seafood by-products, and digital ocean monitoring.

The findings have been categorised along seven key technological domains: biomass production, biorefining and processing, biotechnology and bioinformatics, automation and robotics, circular economy integration, infrastructure and logistics, and policy/data ecosystems. These categories were used to synthesise the cross-cutting needs and illustrate the differences and commonalities among regions and sectors.

Finally, the report serves as a basis to inform ongoing and future matchmaking activities through the Blue Bio Match platform. The insights collected support the design of innovation support mechanisms and guide regional cooperation efforts. This work will also contribute to the final deliverables of the project and support the identification of future innovation pathways within the European blue bioeconomy.

Introduction

The European blue bioeconomy is still emerging as a strategic domain linking marine ecosystems, biotechnology, and circular economic models; with increasing demand for sustainable bio-based solutions, blue bioeconomy technologies have received growing academic and policy interest. Recent literature underscores the strategic relevance of blue bioeconomy technologies in driving sustainable growth within marine and coastal regions across Europe, for instance, the European Commission's Blue Economy Report (2022) and Bioeconomy Strategy (2018) emphasise the potential of marine biotechnology, algae valorisation, and aquaculture waste utilisation to contribute to climate neutrality and circularity goals. Also, the rapid expansion of blue biotechnology, desalination, and marine living resources, with a 24 % rise in profits for fisheries and aquaculture and a 45 % surge in offshore wind GVA, reinforces the priority of marine bio-based innovation (EU Blue Economy Report 2024).

The transition toward a sustainable blue bioeconomy across European coastal regions demands to couple ecological resilience with inclusive economic development. This transition requires a delicate alignment of scientific innovation, regional policy coherence, and collaborative governance to unlock the potential of marine biological resources while preserving the integrity of the marine environment. In this context, it is quite relevant to perform a strategic identification of regional technological gaps that hinder the efficient and sustainable exploitation of marine biomass. These bottlenecks obstruct not only industrial development but also the capacity to establish circular and regenerative economic models that valorise marine resources and could promote regional economic development and coastal resilience with a broader implementation of circular bio-based models aligned with the EU Green Deal and Blue Growth strategies.

This document presents a synthesis of region-specific technological needs, drawing upon key findings from the BlueBioClusters (BBC) project, notably Deliverables D4.3 (Technology Mapping), D2.4 (Value Chains), D5.2 (Challenges by Sub-Sector), and D5.3 (Co-Creation Workshops) as well as the outcomes from WP4 actions linked to technology assessment as well as some examples from **Blue Bio Match** product showcase on technology suppliers. The objective is to provide an integrative analysis of region-specific technological demands, consolidating the different resources approached in the framework of the project. These findings reflect the synthesis of empirical data collected through stakeholder consultations, participatory workshops, and value chain assessments. This analysis also reflects insights drawn from stakeholder interactions facilitated through matchmaking events, support mechanisms for startups and SMEs, and a regional inventory of regulatory and infrastructural barriers. The objective of this report is: first, to delineate a taxonomy of technological gaps and needs that recur across regional ecosystems; and second, to inform multi-level governance structures and foster transregional cooperation, enabling the European Union's coastal regions to lead the global transition toward a bio-based blue economy.

Blue Bioeconomy technologies

As already stated in BBC's framework, the blue bioeconomy has a relevant dynamic in technological innovation in Europe, driven by the sustainable utilisation of marine biological resources and it encompasses a wide array of fields, from biomass valorisation and marine biotechnology to aquaculture engineering and digital integration; each contributing to new bio-based products, processes, and value chains. The sustainable development of the sector is quite complex because it is driven par various aspects including the blue biomass (fish, algae, crustaceans, bivalves, etc.), the dynamic ecosystem of living resources, the application market, the regulatory frameworks and the technological needs.
Amongst the more predominant technological trends in blue bioeconomy, we can find the following:

Marine Biomass Valorisation Technologies

Technological innovations in this area include cascade biorefining techniques, supercritical CO_2 extraction, enzymatic hydrolysis, and fermentation processes. These methods enable the production of diverse end-products such as bio-based plastics, cosmetics, food additives, and agricultural inputs. Pilot projects have demonstrated the feasibility of converting marine biomass into high-value compounds. Araújo et al. (2021) review processing technologies for macroalgae biorefineries, highlighting enzymatic hydrolysis, supercritical extraction, and cascade bioprocessing as key methods. Other authors, such as Biancarosa et al. (2020), investigate the integration of algae into animal and fish feed, emphasizing nutrient efficiency and circularity.

Marine Biotechnology and Bioactives

Marine biotechnology leverages genomics, metabolomics, and synthetic biology to explore the biochemical potential of marine organisms, including bacteria, microalgae, fungi, and invertebrates. Advances in high-throughput screening and omics technologies are accelerating the identification of novel bioactive compounds with applications in pharmaceuticals, nutraceuticals, and industrial enzymes. Bioprospecting of marine environments—particularly extreme habitats like deep-sea vents—has uncovered a wealth of untapped biodiversity. The bioactive potential of marine-derived compounds includes antioxidants, enzymes, and antimicrobials (Kim & Wijesekara, 2019; Voulvoulis, 2020). Recent advances in omics technologies, bioinformatics, and synthetic biology have accelerated the identification of promising strains (Sasso et al., 2021).

Aquaculture Engineering and Integrated Systems

Recirculating Aquaculture Systems (RAS) have emerged as a key solution for water-efficient and land-based production. In parallel, Integrated Multi-Trophic Aquaculture (IMTA) offers a systems-level approach to nutrient recycling, combining finfish, shellfish, and algae in symbiotic setups (Chopin et al., 2019 and Buck et al., 2020). Sensors, automated feeders, and AI-powered biomass estimators are being deployed to optimise feeding and

environmental management.

Digital Technologies and Smart Infrastructure

The Internet of Things (IoT) devices enable real-time monitoring of water quality, fish health, and biomass productivity, new technologies are exploring the use of IoT, AI, and blockchain in traceability and environmental monitoring (Fernández-Caramés & Fraga-Lamas 2020). Artificial intelligence is being applied to predictive modelling, disease detection, and supply chain optimisation. Blockchain-based systems have been piloted for traceability in fisheries and aquaculture, ensuring product authenticity and regulatory compliance.

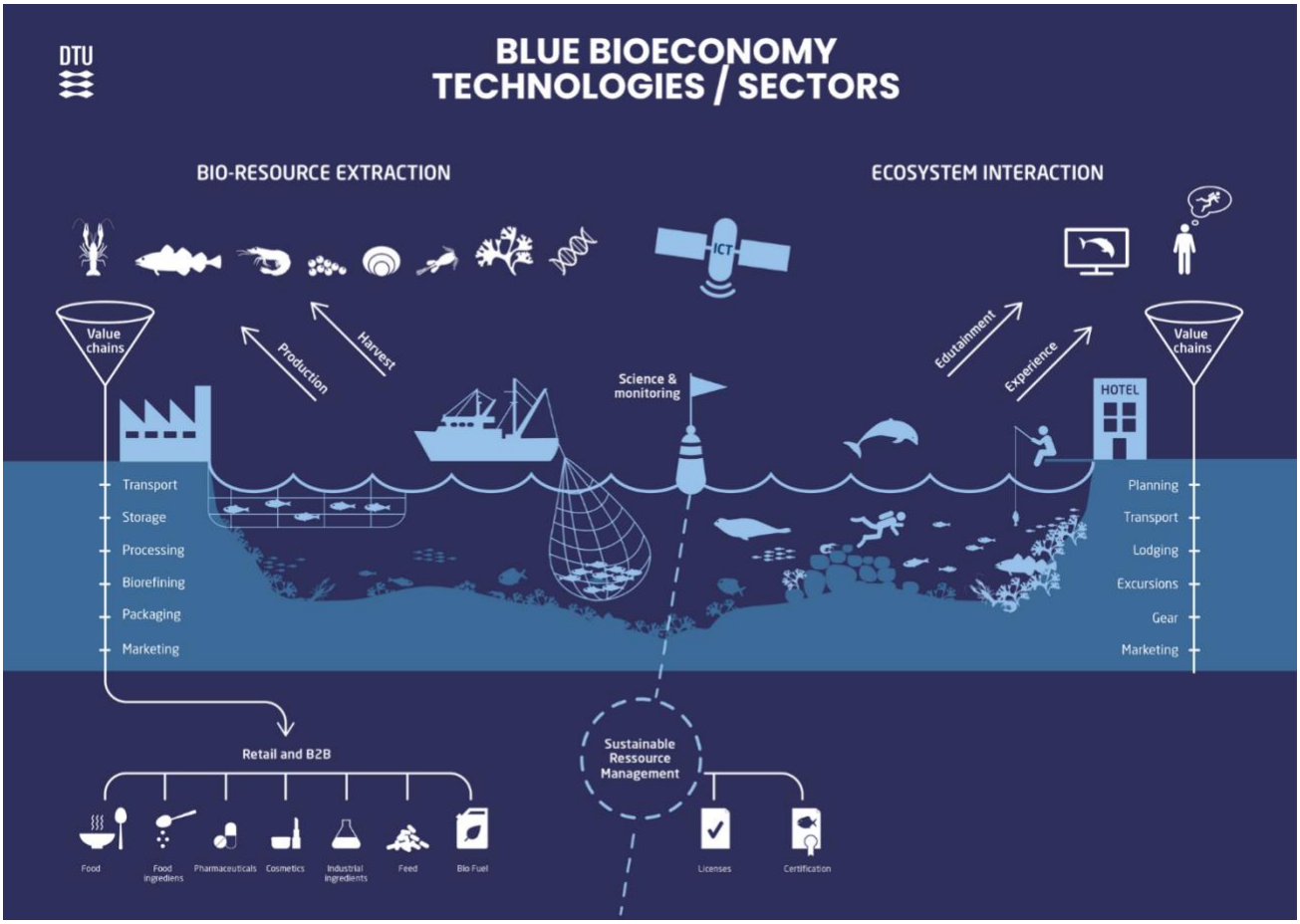

Figure 1 illustration of the main sectors and potential technologies of the blue bioeconomy sector – adapted from DTU Aqua. https://www.aqua.dtu.dk/english/topics/blue-bioeconomy

Methodology

In order to establish the technological needs in the BBC regions. All partners were engaged in the identification of stakeholders through the development of the BBC database, as mentioned in previous deliverables. This database gathers different stakeholders, such as technology suppliers, users, researchers, investors, associations, etc.; they are also categorised by type, region and sector. This information, coupled with the work undertaken in Blue Bio Match as well as in the other work packages, allowed the consortium to engage

with key actors in the blue bioeconomy sector.

Regarding the technological needs in the different regions, some inputs from other deliverables have been considered and consolidated. Notably, D2.4 Final Report on BlueBioClusters Value Chains, D4.3 Technologies mapping, D5.2 Summary of main challenges by sub-sector (the technology challenges/needs), D5.3 Results from Regional Co-Creation Workshops/ Transnational Bootcamps (the workshops and webinars on Technology). Moreover, 21 interviews have been conducted to analyse the technological needs of the stakeholders. All this information has been collected and integrated with a bibliographic review and the current status of the technological needs and trends in Europe.

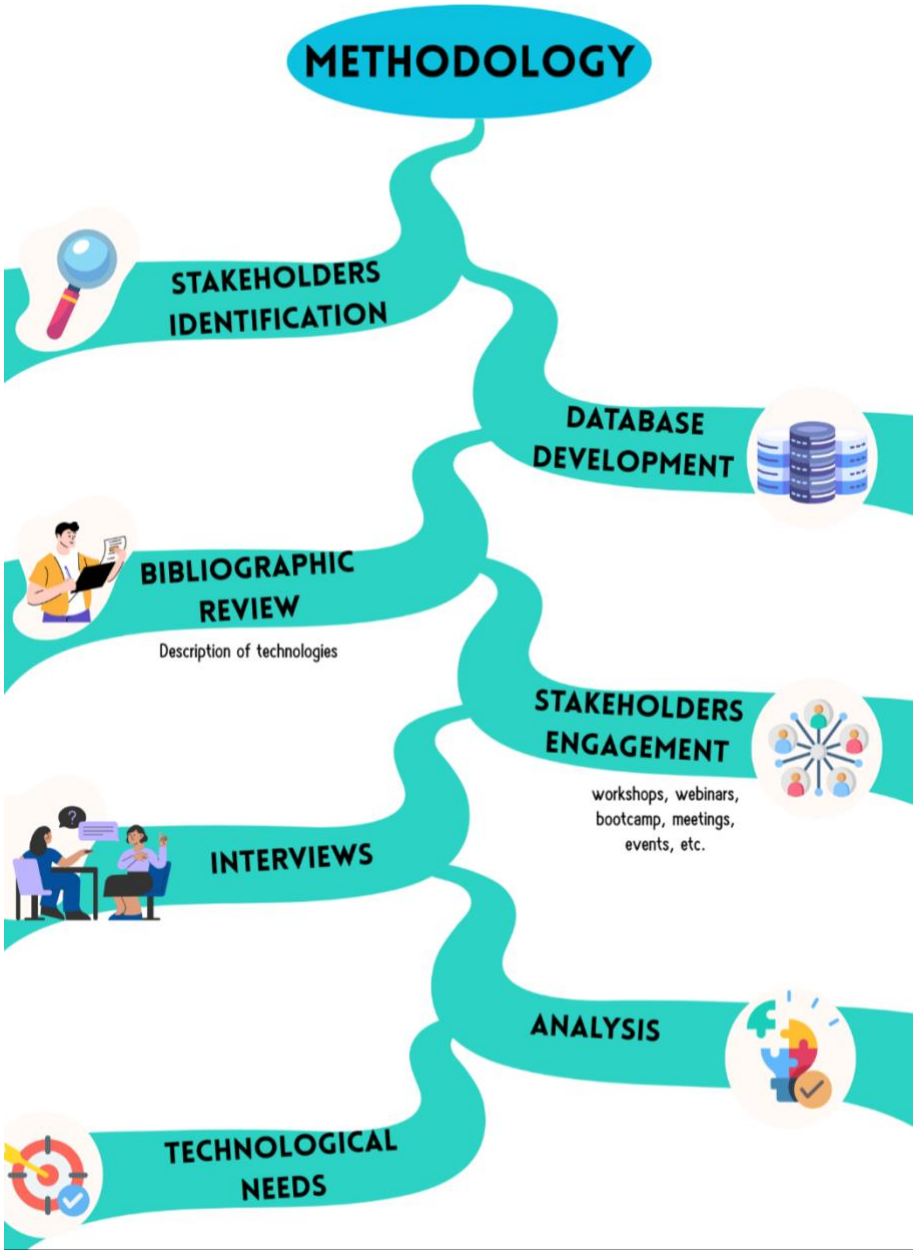

Figure 2 Methodology used for the D4.5 Report on technology needs in regions

Technology needs in the BBC regions

The BBC consortium encompasses 9 regions along the coastal areas in Europe. As mentioned above, the blue bioeconomy sector is key for the sustainable use of aquatic and marine biological resources for economic growth, improved livelihoods, and environmental health. In the development of the blue bio-based value chains, the regions are facing several technological needs, which can be sorted by

1. Sustainable Biomass Production

- Advanced aquaculture systems: Recirculating aquaculture systems (RAS), offshore and integrated multi-trophic aquaculture (IMTA) for efficient, low-impact production.
- Selective breeding & genomics: For disease resistance and faster growth in farmed species.
- Precision farming tools: Sensors, IoT, and AI to monitor and optimize water quality, feeding, and fish health.
- Algae cultivation technologies: Photobioreactors and open-pond systems with high yield and low footprint.

2. Biorefinery and Processing Technologies

- Biorefining platforms: To convert marine biomass (e.g., algae, fish waste) into multiple high-value products (nutraceuticals, cosmetics, biofertilizers, etc.).
- Green extraction technologies: Enzyme-assisted, supercritical CO_2, and microwave extraction to obtain bioactive compounds sustainably.
- Cold chain and preservation tech: Especially important for remote or offshore biomass sources.

3. Biotechnology and Bioinformatics

- Marine biotechnology tools: For exploring marine genetic resources (e.g., metagenomics, synthetic biology) and developing novel bio-based products.
- Digital bioinformatics platforms: To manage genomic, proteomic, and metabolomic data from marine organisms.
- CRISPR and genetic engineering: For developing resilient strains of algae and other aquaculture species.

4. Monitoring, Automation, and Robotics

- Underwater drones and ROVs: For monitoring aquaculture systems and assessing marine biomass.
- Autonomous monitoring systems: For real-time data collection on environmental conditions, plankton blooms, and pollution.
- AI and big data analytics: For predictive maintenance, ecosystem impact assessments, and production optimization.

5. Circular Economy and Waste Valorisation

- Waste-to-resource technologies: Using seafood processing by-products for

bioenergy, bioplastics, and animal feed.
- Water recycling and nutrient recovery: Especially in land-based aquaculture systems.

6. Logistics, Infrastructure, and Market Integration
- Decentralized processing units: Near biomass sources to reduce transport costs and emissions.
- Blockchain and traceability tech: For certification, safety, and origin tracking in supply chains.
- Digital marketplaces: For matching supply and demand in emerging blue bio-based sectors.

7. Policy, Regulatory, and Data Infrastructure
- Open-access marine data platforms: Harmonized databases for oceanographic, ecological, and economic data.
- Decision-support systems: For policymakers and investors to assess sustainable development scenarios.

Cross-Cutting Technological Needs Across Regions

Across all partner regions, several technological needs are shared, notably the most prominent is the consistently low Technology Readiness Levels (TRLs) of innovations related to marine biotechnology and by-product valorisation. Numerous promising ideas are stalled in the early stages of development, unable to transition into demonstrators or pre-commercial applications due to the absence of critical scale-up infrastructure such as pilot facilities, testing laboratories, and validation platforms. This lack of infrastructure limits the ability of SMEs, startups, and research groups to test market hypotheses and attract private investment. Many SMEs lack the capacity to navigate regulatory frameworks or access pre-commercial piloting environments. This reveals a structural disjunction between the ideation phase and sustainable scale-up, further complicated by inconsistent regional support mechanisms.

Digital transformation within the sector also remains limited. Despite increasing interest in integrating smart systems into aquaculture and marine biomass processing, the actual uptake of technologies such as artificial intelligence (AI), Internet of Things (IoT), and blockchain remains minimal. Real-time environmental monitoring, automated biomass handling, and integrated data systems are often absent or function in isolation. This fragmentation not only compromises operational efficiency but also diminishes resilience in the face of environmental stressors and market volatility.

Another structural challenge is the fragmentation of knowledge transfer mechanisms. The interface between academia and industry is often characterised by weak or informal linkages, resulting in poor diffusion of research-based innovations. Research institutions typically focus on fundamental investigations, while industry actors struggle with regulatory constraints, funding limitations, and operational challenges. As a result, there is a widespread gap in technology transfer mechanisms between academic research and industry applications;

consequently, there is a pressing need to institutionalise translational mechanisms that can broker partnerships, de-risk innovation, and facilitate intellectual property transfer across organisational boundaries.

Technological needs per region

Belgium's microalgae sector is small but growing. However, its development is hampered by technological and regulatory barriers, particularly in terms of upscaling, water use restrictions, and nutrient recycling. Valorisation of biomass by-products is rare, in part due to the absence of economic incentives and processing capabilities. A stronger focus on closed-loop water systems, improved photobioreactor technologies, and nutrient recovery processes could unlock new value propositions for the sector. Specific issues identified include:

- Seaweed Farming Integration
- Integration difficulties due to water quality

Estonia's blue bioeconomy remains in its formative stage, with structural gaps in infrastructure for aquaculture innovation. The technological basis for integrating aquaculture with renewable energy platforms, such as offshore wind farms, is not yet established. Moreover, solutions to valorise beached macroalgae—often seen as waste—into high-value agricultural inputs are largely absent. These deficiencies constrain Estonia's capacity to scale sustainable aquaculture and limit its contribution to nutrient recirculation in the Baltic ecosystem. Specific issues identified include:

- Lack of appropriate technological solutions hinders the development of nature-friendly aquaculture systems and fishing gears. Additionally, there's a need for sustainable technologies for utilizing seaweed for fertilizer and agriculture growth substrate production, but scarcity of necessary investment measures poses a challenge.
- Increasing the transmission capacity of power lines is crucial for the development of offshore wind farms and hybrid parks, combining different aquaculture farms.
- There is a moderate political interest in addressing the underdeveloped IT solutions in rural areas.

In **France**, the blue bioeconomy faces both operational and strategic hurdles. The commercial emphasis on whole-product shellfish marketing restricts the generation and recovery of valuable by-products. There is a pronounced lack of trained personnel in emerging bio-based technologies, alongside low levels of cross-sectoral collaboration. Regulatory complexity, particularly in relation to food safety and environmental standards, adds further obstacles to the industrial exploitation of blue biotechnologies. These limitations underscore the need for coordinated investment in bioprocessing pilot facilities and upskilling programmes. Further needs of the region include:

- Advanced cultivation systems:
- Offshore and coastal seaweed farms with improved anchor/mooring technology.
- Photobioreactors optimized for microalgae species like Tetraselmis and Isochrysis.
- Breeding and domestication of native algae species for higher yield, disease

resistance, and bioactive compound content.
- Sustainable harvesting equipment for wild seaweed beds with minimal ecosystem disturbance.
- Drying, stabilization, and preservation technologies to maintain bioactivity post-harvest.
- AI for screening and molecular modelling: Accelerating the discovery of applications in health, nutrition, and cosmetics.
- Waste valorization: Use of aquaculture and fishery waste streams (e.g., shells, fish skins) for chitin, collagen, and other bioactives.

Iceland exhibits scientific excellence in marine microbiology and bioactive compound discovery. However, the absence of commercial-scale fermentation, bioreactors, and downstream processing systems limits industrial scalability. Sea cage aquaculture, a significant part of the Icelandic blue economy, faces challenges related to disease prevention, biosecurity, and containment. Investment in real-time environmental diagnostics and sensor networks is critical to preserving both the ecological and commercial viability of this sector. Technological needs and challenges include:
- Lack of infrastructure.
  - Infrastructure limitations for sludge and mortalities from salmon aquaculture.
  - Supply challenges of raw materials like crustacean shells.

Lithuania is in the early stages of building a marine biotechnology sector. It is heavily constrained by seasonal fluctuations in biomass availability and lacks adaptive storage and processing infrastructure. Moreover, the capacity to cultivate and optimise marine microorganisms for bioproduct development remains limited. Investments in dynamic cultivation systems, microbial consortia optimisation, and long-term biomass preservation technologies would significantly increase resilience and output. Challenges include:
- Challenges in aquaculture due to low diversity of cultured species, particularly catfish dominating in Recirculating Aquaculture Systems (RAS), and low growth potential in pond aquaculture

Norway's challenges are largely systemic. Its mature aquaculture and fisheries sectors are still based on linear value chains, making integration of circular processes difficult. Innovative technologies for nutrient recovery, product diversification, and biomass fractionation exist, but their implementation is constrained by spatial planning and a lack of digital traceability standards. Interoperable technologies that facilitate the co-location of different marine uses and enable full-cycle monitoring are necessary to achieve a regenerative production model.

Portugal experiences parallel constraints, particularly in the realm of technology validation and deployment. Small-scale innovators and research entities face difficulties in accessing cost-effective, shared infrastructure for downstream processing, biocompatibility testing, and formulation development. Furthermore, the integration of ICT solutions in production environments remains weak. Digital innovation ecosystems are still embryonic, and cross-

platform interoperability among marine actors is minimal. Addressing these gaps is essential for improving the competitiveness of marine biotech ventures.

In **Scotland**, the emphasis is increasingly placed on decentralised, low-impact aquaculture systems that are compatible with remote coastal environments. However, technological infrastructure for the valorisation of algal residues and fish processing waste is still inadequate. The country's limited biotechnology prototyping capacity also hampers the ability of researchers and entrepreneurs to validate new products under real-world conditions. Enhanced access to bioincubators and flexible processing lines would support rapid iteration and innovation. Specific challenges include:

- Concerns about sea water rearing and sea lice with emphasis on environmental aspects like water quality.

Sweden contends with a set of specific technological limitations, particularly in relation to the sustainable exploitation of bivalves and macroalgae. Limited access to mechanised systems for harvesting and post-harvest processing, coupled with underdeveloped antifouling technologies, continues to reduce sectoral productivity. Climate-induced variability and the encroachment of invasive species demand adaptive infrastructure and more dynamic environmental monitoring tools that are currently lacking.

Region	Summary of Technology Needs
Belgium	Difficult to find valorisation for oyster shells | waste minimize waste (crushed shells) in harvest methods, increase harvest volumes reduce shell crush - need for improved mussel harvest methods to reduce crushing.
Estonia	Nature-friendly aquaculture systems need to be developed. | There is a need to develop nature-friendly fishing gears. | Fish stocks need improvement. | Offshore wind farms. | Hybrid parks combining different aquaculture farms. | There is a need for the development of sustainable technologies that allow the use of seaweed piled on the beach for fertiliser production. | There is a need for the development of sustainable technologies that allow the use of seaweed piled on the beach for agriculture growth substrate production. | Underdeveloped IT solutions in rural areas.
France	Shellfish residues is difficult to mobilize | as these products are sold "whole", | Some of the viscera are thrown back into the sea because their commercial value is too low and they are highly perishable. | The confidentiality of intellectual property, which locks some solutions. | Loss of competitiveness for French companies| insufficient level of qualification in emerging technologies and insufficient transfer to industry. | Understanding

	algae blooms is important for optimal placement of growing sites to avoid toxins.
Iceland	Sea cage salmon farming in Iceland faces some challenges related to the escapes of farmed fish into the wild, bad for environment and company image that require improve prevention and management technologies to reduce the risk and impact of such events. | The scale of cultivation waits for technological development.
Lithuania	Low diversity of cultured species: catfish in RAS dominated. | Low growth potential in pond aquaculture sector. | Low applications of innovations. | Lack of know-how at development stage (innovations).
Norway	Fish's stomach contents can destroy the facility machinery. | Missing competence for other utilization need for technological innovations that require significant and risky investments | Research regarding the impacts of changing marine biological processes related to ex. climate change are needed. These are potential threats to successful cultivation
Portugal	Missing capacity to replicate bioresources in laboratory. | Difficulty in accessing water test facilities. | Harvesting and sampling approaches are not adequate to biodiscovery | Difficulty in hiring specialised human resources. | Difficulty in getting sustainable and reproducible batch supply (adequate culture / harvest, adequate manufacturing technologies, adequate volumes yield). | Lack of innovation department / staff. | Difficulty with separation and purification downstream protocols. | Difficulty in discovering novel marine natural products and bioactives. | Difficulty with safety and efficacy testing protocols and timeframes. | Difficulty in innovating on screening technologies and platforms. | Logistics too complex or heavy. | Lack of knowledge on the predicted / desired route of administration / type of formulation for final application. | Difficulty in accessing laboratory spaces. | Difficulty in accessing water test spaces.
Sweden	There are valuable proteins and other properties in the side streams to explore valorisation but no process available for side-stream processing, need for technology to extract valuable products. | calcium deposits from "spiral worms" make the shells unattractive to consumers, increases waste streams, research on methods of reducing this "fouling" of mussel shells, or side-stream valorisation methods to use the extra calcium. | Testing and monitoring of algae blooms - better system needed - today it takes too much time and is done by hand/boat - could be automated. | Invasive species (sea squirts) attach to the ropes, outcompete mussels and reduce the volumes in cultivation. Methods needed to reduce the amount of sea squirts growing on ropes - or to harvest and sell sea squirts as a secondary revenue stream. | Mussel filaments - contribute to the problem of crushed shells in processing as they are difficult to remove in separation. Need for research and process technology - a process to "loosen" the filament

	material. | Challenges lie in the scale up of production and finding the right type of process design to make use of the raw material to 100 percent and make sure no side streams go to waste.

Table 1. Summary of technological needs per region

Common challenges and technological priorities

From the regional analyses, several priority domains emerge that deserve targeted investment. Chief among these is the need for scalable, modular biorefinery infrastructure that can accommodate heterogeneous feedstocks and produce multiple value streams through integrated processes. Such facilities should be distributed regionally, equipped with flexible units, and capable of adjusting to the seasonal and geographical variability of marine biomass.

Parallel to this, sensor-based systems for aquaculture and biomass management require immediate attention. These include underwater cameras, biosensors for disease detection, nutrient flow monitors, and automated feeding systems. Coupling these technologies with cloud-based analytics and decision support tools would enable producers to optimise outputs while reducing environmental impacts.

Extraction technologies that utilise green chemistry principles are also essential. Processes based on supercritical CO2 extraction, enzymatic hydrolysis, and membrane separation offer alternatives to conventional solvent-based methods. These techniques should be embedded within closed-loop processing frameworks that prioritise energy efficiency and minimal waste.

To enhance the effectiveness of technology development and deployment, support packages for SMEs should include access to legal and regulatory coaching, business acceleration services, and tailored mentorship. Furthermore, regional matchmaking platforms should be institutionalised as permanent fixtures in the innovation ecosystem, offering regular touchpoints between entrepreneurs, investors, and policy enablers.

Finally, bridging the research-to-market gap will require the institutionalisation of innovation brokerage platforms. These platforms should support matchmaking between SMEs and researchers, facilitate access to investment, and provide regulatory guidance. Blue Bio Match and similar networks could serve as the backbone of such efforts, enabling the alignment of regional innovation agendas and fostering an inclusive blue bioeconomy ecosystem.

Interviews – results & analysis

The consortium has conducted a total of 25 interviews from the different BBC regions. The interviewees were technology suppliers and users. The interviews were conducted during the regional bootcamps and some of them were complemented afterwards in bilateral meetings or other activities of the project (co-creation workshops, events, webinars, etc.). Due to the complexity of the sector and the differences in TRLs, size of the companies, biomasses and

targeted markets, the results were diverse and therefore they have been harmonised as much as possible. The main outcomes are described per country in the next section.

Iceland

Common Technological Gaps Identified

Pilot Testing Infrastructure

Across all interviews, limited access to pilot-scale infrastructure was reported as a critical bottleneck. Startups in early TRLs (1–4) emphasized the lack of facilities for:

- Small-batch fermentation
- Microalgae cultivation in saltwater conditions
- Sustainable leather processing without upfront equipment investments

There is a clear need for **shared pilot labs and testbeds**, especially adapted to saline environments and by-product processing.

Scale-Up and Manufacturing Technology

Startups approaching market (e.g. Marea, TRL 9) face challenges related to:

- Cost-effective large-scale production systems
- Custom equipment development, such as spray coating systems or tanning machines

Scaling technologies and automation systems are lacking in Iceland's current infrastructure. Partnerships with engineering firms or access to modular pilot platforms could mitigate this.

Specialised Extraction and Bioprocessing

All four concepts involve transforming marine biomass—whether fish skin, by-products, or algae into high-value materials. This demands:

- Specific extraction technologies (enzymatic, mechanical, chemical).
- Custom formulation adjustments based on biomass characteristics.
- Development and access to flexible bioprocessing technologies that can be adapted to different feedstocks is a recurring need.

Startup	Sector	TRL	Key Tech Needs
Lara Malta	Microalgae / Feed	1–2	Access to tech for microalgae cultivation in aquaculture wastewater
Marea ehf.	Packaging / Biomaterials	9	Equipment for upscaling organic coatings, formulation adaptability
Nanna Lín	Leather / Biodesign	3	Tanning machinery, drying solutions, mechanical

Startup	Sector	TRL	Key Tech Needs
			finishing tools
Vahid Abbasi	Feed ingredients	4	Fermentation scale-up systems, valorisation of fish waste streams

Table 2 Summary of key technological needs from the 4 companies interviewed in Iceland

Perceived Barriers to Access

While most founders are aware of the existence of required technologies, they cite the following barriers:

- High upfront costs for industrial equipment.
- Lack of access to relevant test platforms in Iceland.
- Fragmentation of R&D support across academia and industry.

Implications for Technology Support Strategies

The analysis suggests three immediate priorities for regional and cross-regional support mechanisms:

1. Investment in shared, modular pilot infrastructure with capabilities for fermentation, aquaculture wastewater treatment, and marine biomass processing.
2. Support for equipment prototyping and custom manufacturing partnerships, particularly for startups entering scale-up.
3. Mentoring and matchmaking with technology developers and facilities in other EU regions to compensate for local gaps.

Sweden

Common Technological Needs and Barriers

Pilot and Processing Infrastructure

Startups at TRLs 2–6 (e.g. AnnaHörling, Alge Lume, Moreshrooms) express strong needs for access to:

- Processing and fermentation facilities tailored to algae, fungi, and shell materials.
- Testing environments to validate material properties and functionality (e.g., air purification or biodegradability).
- Small-batch production tools to prototype and iterate physical products.

There is a mismatch between the highly specific biomass sources used and the availability of appropriate processing tools.

Scale-up and Product Integration

Startups near-market (TRL 9) like SeaMe AB and Glufs AB report challenges in:

- Upscaling production efficiently to meet growing demand.
- Integrating their products into existing market value chains (pet food retail, aquaculture gear).
- Automating or outsourcing parts of the production process.

Upscaling technology is not necessarily missing, but it is expensive and often not tailored to marine-origin products.

Cross-sectoral Technological Collaboration

Several companies express a need for partnerships with experts in:

- Materials science (oyster shell degradation, biocomposites).
- Cultivation systems (microalgae growth under indoor conditions).
- Digital solutions for traceability or smart device integration.

Startups in niche areas need access to multi-disciplinary technical expertise.

Startup	Biomass Source	TRL	Sector Focus	Tech Needs Summary
SeaMe AB	Fishing gear	9	Blue biotech / gear	Production integration, business scaling
Moreshrooms AS	Macroalgae + fungi	5	Biotech / alternative protein	Bioprocessing, fermentation support
Glufs AB	Mussels	9	Pet food	Market logistics, marketing skills
AnnaHörling	Oyster shells	2	Circular materials	Biodegradation testing, design integration
Alge Lume	Microalgae	6	Bio-based design	Cultivation tech, material testing

Table 3 Summary of key technological needs from 5 companies interviewed in Sweden

Cross-Cutting Needs

- Affordable pilot-scale units for algae/fungi fermentation and processing.
- Bio-based material labs for developing marine-origin construction/design products.
- Testing facilities for validating functionality (e.g., air purification, durability).

- Knowledge transfer with experts in marine biotechnology, materials engineering, and digital product design.

Recommendations

- Connect Swedish startups to transregional facilities and test beds (e.g., algae cultivation platforms, symbiosis parks).
- Expand access to multi-use labs supporting early TRLs with modular tech configurations.
- Foster public-private partnerships with universities and incubators to provide applied R&D support for marine biomass valorisation.

Norway

Current Conservas AS:

- Reviving Norway's canned seafood sector by introducing small-batch, high-quality fish products aimed at both B2C and B2B markets.
- **Current Technology Status**: TRL 1, early concept phase with some exploration into traceability systems (inspired by "FollowFood" in Germany).
- **Technological Needs**:
  - Packaging innovation: Sustainable, consumer-friendly materials.
  - Traceability and tracking systems: Especially for sourcing and consumer transparency.
  - Heavy metal and contaminant testing technologies: Particularly important for food safety and certification.
- **Access Barriers**:
  - Absence of test-scale canning lines in Norway.
  - Lack of dedicated pilot production environments for small-scale preservation trials.
- **Strategic Gap**:
  - The Norwegian infrastructure for artisanal or niche-scale seafood processing is underdeveloped.

There is a pressing need for micro-scale modular processing facilities and traceability tools tailored to artisanal marine food producers.

Nuas Technology AS

- Industrial-scale hydrolysis of fish residuals to produce high-quality food ingredients (proteins, oils, bone material).

- **Current Technology Status**: TRL 7–8. Pilot plant constructed and tested on salmon residuals, ready for commercial deployment.
- **Technological Needs**:
  - Cooling equipment: For maintaining ingredient stability post-processing.
  - Logistics infrastructure: Cold chain management and integration with food-grade production facilities.
  - Operational scale-up tools: Such as automation systems, safety control, and biochemical validation protocols.
- **Access Barriers**:
  - Most of the needed technology exists on the market, but investment is required for adaptation and installation.
- **Strategic Gap**:
  - Absence of in-house expertise in biochemistry and food processing, which slows internal innovation and certification.

Nuas's technology need is not about invention but about integration, reliability, and rapid deployment of proven tech at industrial scale.

Dimension	Current Conservas AS	Nuas Technology AS
TRL	1	7–8
Technology Gap	Lack of basic facilities (testbeds, tools)	Integration of existing tech (cooling, logistics)
Key Sectoral Need	Food preservation & traceability	Residual biomass valorisation
Infrastructure Requirement	Small-scale canning & packaging platform	Industrial production site & utilities
Innovation Barrier	Access to test environments	Access to capital and skilled staff

Table 4 Summary of key thematics and technological needs from 2 companies interviewed in Norway

Implications for Regional Tech Support

These two cases highlight distinct categories of technological needs:

- Startups in ideation or low TRLs (e.g., Current Conservas) need:
  - Access to pilot-scale food tech facilities.
  - Support for packaging and preservation technology trials.
  - Affordable access to traceability systems and food safety testing.
- Startups approaching commercialisation (e.g., Nuas Technology) need:

- Support for scaling validated technology.
- Access to logistics systems and production sites.
- Recruitment or connection to biochemical/food science expertise.

Baltic basin – Estonia & Lithuania

Vetik (Estonia)

- **Tech Focus:** Development of seaweed-based biostimulants for agriculture.
- **Challenges:**
  - Inconsistent extract performance across soil types.
  - Limited capacity for field trials due to financial and human constraints.
  - Regulatory needs for CE marking and contamination control.
- **Tech Needs:**
  - Field trial infrastructure
  - Consistent extraction systems
  - Expertise in regulatory affairs and microbiological testing
  - Exploration of bioplastic potential from polysaccharides.

2. Sequench (Lithuania)

- **Tech Focus:** Environmental DNA (eDNA) for biodiversity monitoring.
- **Challenges:**
  - Market adoption by private sector clients.
  - Limited access to marketing and commercialization expertise.
- **Tech Needs:**
  - Refinement of air sampling protocols
  - Marketing and business development capacity
  - Scaling up sample processing without loss of accuracy.

3. Ruhnu Kultuuriruum (Estonia)

- **Tech Focus:** Integrating macroalgae into local food offerings.
- **Challenges:**
  - Early-stage concept with no tested cultivation.
  - Regulatory uncertainty and lack of farming knowledge.

- **Tech Needs:**
  - Pilot-scale macroalgae cultivation systems.
  - Access to legal and permitting expertise.
  - Processing and kitchen technology for recipe development.

4. QLT (Lithuania)

- **Tech Focus:** Vertical shrimp farming tanks**.**
- **Challenges:**
  - Funding barriers to prototype refinement and scale-up.
  - Need to integrate microalgae production into the system.
- **Tech Needs:**
  - Tank optimization technology
  - Microalgae cultivation know-how
  - Business development support and financial planning

5. Blue Anew (Estonia)

- **Tech Focus:** Blue economy education; future project in seaweed.
- **Challenges:**
  - Skills gap in sustainable blue teaching.
  - Difficulty accessing regional policymakers.
- **Tech Needs:**
  - Communication and stakeholder engagement tools
  - Curriculum development tech platforms
  - Long-term: tools for seaweed cultivation/pedagogical integration.

Cross-Cutting Technology Needs

Category	**Common Needs**
Pilot Infrastructure	Algae cultivation systems, biostimulant test plots, aquaculture tank trials
Process Optimization	Consistency in bio-extracts, stable eDNA sampling, energy-efficient aquaculture
Digital Tools	eDNA databases, stakeholder communication interfaces, traceability platforms

Category	Common Needs
Regulatory Navigation	CE marking for bioproducts, algae farming permits, blue policy frameworks
Expertise Access	Specialists in algae processing, biostimulants, marketing, regulation
Market Testing and Validation	Farmer trials, restaurant partnerships, institutional uptake assessments

Table 5 Summary of cross-cutting technological needs from the companies interviewed in Baltic basin

Key Insights

- **Technology Readiness Gaps**: Most Baltic startups remain in early to mid-TRL stages (3–6). Validation through pilots and expert feedback is a limiting factor.
- **Infrastructure Mismatch**: There is a gap between available infrastructure (labs, farms, processing) and what startups need for specific blue bio-based technologies.
- **Human Capital Needs**: Many teams are small and lack dedicated technical, marketing, or business development staff. Upskilling and mentoring are urgently needed.
- **High Innovation Potential**: Despite their early stage, all startups align with circularity, local biomass use, and smart specialisation in their regions—if supported by proper tech ecosystems.

Portugal

Aquaponics Iberia

- A modular, large-scale aquaponic system (SWIMS™) with real-time data-driven control.
- **TRL Status**: Near-commercial deployment (TRL 9 for multi-modular systems).
- **Tech Needs**:
  - AI Decision Systems: To optimize production cycles based on local variables like demand, crop yield, and climate.
  - Energy Efficiency: Advanced water heating or temperature control systems are needed to reduce energy costs.
- **Barrier Level**: Moderate — technology likely exists, but solutions must be tailored and cost-effective.
- **Strategic Gap**: Market-specific algorithms for AI and low-cost energy recovery systems for thermal control.

Clean Valley

- Polyculture algae reactors for plug-and-play wastewater treatment in aquaculture.
- **TRL Status**: Pilot-level testing and early field deployment (TRL 8).
- **Tech Needs**:
    - Pilot Sites: Validation in operational environments is critical.
    - Modular Scaling: Adapting polyculture-based bioreactors for diverse client ecosystems.
- **Barrier Level**: High — while the technology is proven, adoption depends on partner engagement and demonstration.
- **Strategic Gap**: Bridging tech-to-market through strategic partnerships and proof-of-value use cases.

Galene Pathways

- Marine ecosystem software integrating machine learning, satellite data, and spatial planning.
- **TRL Status**: Backend complete (ML models, data pipeline); frontend in progress (TRL 6).
- **Tech Needs**:
    - UX/UI Development: A usable and interactive dashboard for data visualization and real-time alerts.
    - User Management Tools: Role-based access and dashboard personalization needed for stakeholder diversity.
- **Barrier Level**: Medium — technical skills needed for frontend delivery, but no deep tech barrier.
- **Strategic Gap**: Access to marine data standardization experts and GUI developers familiar with environmental datasets.

SEAentia

- RAS aquaculture of corvina (Argyrosomus regius), no antibiotics or chemicals.
- **TRL Status**: Fully validated commercial operations (TRL 9).
- **Tech Needs**: None declared currently, though indirect needs in marketing and scale-up management are evident.
- **Barrier Level**: None for core tech; minor barriers in growth support (marketing, financing).
- **Strategic Gap**: Brand positioning in high-value B2B seafood markets and global scaling of RAS units.

Technological Needs overview

Startup	Focus Area	TRL	Key Technology Need(s)
Aquaponics Iberia	Closed-loop aquaponics (SWIMS™ tech)	8–9	AI for decision support in crop/fish optimization; energy-efficient heating systems
Clean Valley	Algae-based wastewater treatment (HaaS model)	8	Pilot clients for validation; scaling modular polyculture reactors
Galene Pathways	Marine conservation software (real-time & ML)	6	Front-end UX/UI development for real-time marine data dashboards
SEAentia	Sustainable RAS-based corvina aquaculture	9	No current tech gaps; future focus on scale-up and marketing support

Table 6 Summary of key technological needs from the 4 companies interviewed in Portugal

Cross-Cutting Technological areas

Domain	Identified Needs
AI & Data Analytics	Real-time production optimization (Aquaponics Iberia); ML for predictive monitoring (Galene)
Energy Management	Cost-effective water heating/thermal systems (Aquaponics Iberia)
User Interface Design	UX/UI and front-end data platform (Galene Pathways)
Modular System Design	Polyreactor scalability (Clean Valley); Aquaponics modularity (Fish n' Greens)
Tech-to-Market Validation	Pilots, user trials, business model scaling (Clean Valley, Aquaponics)
Environmental Integration	Ecological sustainability baked into system design (all startups)

Table 7 Summary of cross-cutting technological needs from the companies interviewed in Portugal

Key insights

- Most startups are at TRL 6–9, indicating ready or near-ready systems in need of demonstration, scale-up, and integration.
- AI and real-time decision support emerges as a priority for systems with environmental variability and production complexity.
- Several startups (Aquaponics Iberia, Clean Valley) highlight a technology-market interface gap—i.e., lack of pilot infrastructure or customers to validate at scale.

- Frontend innovation is as essential as backend tech—especially in data-driven platforms like Galene Pathways, which require stakeholder usability for impact.
- A shared emphasis on environmental sustainability and circular economy drives not only tech features but also adoption strategies.

France

Agriloops (Saltwater Aquaponics)

- Pioneering *saltwater aquaponics,* combining shrimp farming with vegetable cultivation.
- **TRL**: 9
- **Current Challenge**: Scaling commercial demonstration farm to produce >100 tons/year.
- **Tech Needs**:
  - Modular expansion-ready systems for other marine species.
  - Optimized logistics and storage tech for short supply chains.
  - Advanced fertilization control using effluents.
- **Strategic Gap**: Extension of saltwater aquaponics tech to new species and climate zones.

Algolesko (Macroalgae Cultivation & Processing)

- Organic open-sea seaweed farming (wakame, kombu) with eco-designed mooring in Natura 2000 zone.
- **TRL**: 8–9
- **Current Challenge**: Diversification into *feed* and *biostimulants* from macroalgae.
- **Tech Needs**:
  - Biorefining processes for algae-to-feed or biostimulant transformation.
  - Access to processing tech for extracts and powders.
  - Market access tech: traceability and product formatting for nutraceutical clients.
- **Strategic Gap**: Lack of processing capacity and R&D for algae-based functional ingredients.

Phosphotech (Marine Biotech)

- Extraction of health-related molecules from fish, mussels, and future oysters.
- **TRL**: 8–9
- **Current Challenge**: Full valorization of marine co-products and reduction of supply chain dependency.

- **Tech Needs**:
  - New extraction technologies for untapped co-products (e.g., mussel shells).
  - Better sourcing logistics to replace New Zealand mussel imports.
  - R&D partnerships for product formulation and bioactivity validation.
- **Strategic Gap**: Upstream raw material constraints and downstream product optimization.

ZENI (Microalgae-Based Water Treatment)

- Photobioreactor system for microalgae-based industrial wastewater recycling.
- **TRL**: 8–9
- **Current Challenge**: Scaling systems and automating algae biomass management.
- **Tech Needs**:
  - IoT-integrated bioreactors with real-time sensors.
  - AI and machine learning for optimizing culture parameters.
  - Automated harvesting and biomass valorization systems.
- **Strategic Gap**: Advanced control systems for high-volume bio-wastewater treatment and biomass logistics.

Common Technology Domains

Domain	Key Needs
Automation & Control	AI-based control for aquaponics (Agriloops) and microalgae systems (ZENI)
Bioprocess Engineering	Algae biorefining for feed/biostimulants (Algolesko), shell digestion (Phosphotech)
Supply Chain Tech	Decentralized logistics and storage (Agriloops, Phosphotech)
Data-Driven Tools	Predictive analytics for water quality (ZENI), traceability (Algolesko)
Modular Scale-Up Systems	Adaptable farming units (Agriloops), scalable reactors (ZENI, Algolesko)

Table 8 Summary of key thematics and technological needs from 4 companies interviewed in France

Environmental and Circular Economy Integration

All four companies are committed to **circular resource use**:

- Agriloops transforms shrimp effluents into fertilizer.
- Algolesko produces seaweed without inputs and within marine conservation zones.
- Phosphotech upcycles fisheries waste for health products.
- ZENI reuses industrial wastewater and converts biomass into fertilizers and animal feed.

Their technologies are inherently aligned with climate resilience, biodiversity preservation, and sustainable food systems.

Key Insights

- All startups are high TRL (8–9), poised for scaling and industrialisation.
- While core technologies exist, the innovation lies in process integration, automation, and application diversification.
- There's a strong need for regional R&D collaboration, especially in biorefinery, AI integration, and bioresource logistics.
- Despite technological maturity, market access and product diversification constraints (e.g., new markets, new formulations) remain barriers.
- Integration of bioprocessing, digital systems, and logistics is a common gap.
- Opportunities exist to share infrastructure or services (e.g., biorefinery units, pilot testbeds).
- There's high demand for public-private R&D partnerships focused on late-stage prototyping and environmental compliance tech.

Blue Bio Match

The Blue Bio Match platform continues to boost the interaction between technology suppliers and users, as well as researchers and other organisations that would like to partner to meet the regional technological needs.
Indeed, one of the tools used for the identification of technological needs is the 'product showcase' catalogue. This catalogue supports the dissemination of technology providers, but it also promotes the interactions with the blue bioeconomy actors across Europe.

Every platform user (currently ca. 1050) can add their product or service to the catalogue by filling in an online form, available here: https://form.jotform.com/240091707627052

In the form, the user is asked to provide the information described in the table below:

Questions	Answer

Write here your product's name	Open end question
What type of product are you submitting?	Cosmetic product
	Ingredient
	Feed product
	Nutra- & Pharmaceutical product
	Food product
	Technology & Machinery
	Other
If applicable, what is the Technology Readiness Level (TRL) of your technology?	Open end question
Write a short description of your product	max 80 characters
Paste here a URL link to your website's product page	Open end question
Upload a product picture that we can use a thumbnail.	Open end question
Describe in one sentence what makes your product sustainable.	Open end question
Do you have any technology needs that you would like the BlueBioMatch community to support you with?	Open end question
Do you offer any technologies that can be of interest for other companies in the Blue Economy?	Open end question
Are you (or anyone in your company) already a registered user on BlueBioMatch?	Yes/No
Please provide us with the name(s) of registered BlueBioMatch user(s) in your company	Open end question
Please tell us your name ...	Open end question
... and provide us with your email address so that we can contact you for additional questions!	Open end question

Table 9 Questions used for the product showcase catalogue on BlueBioMatch

Currently, 23 products are included on the product showcase page. Below are short summaries of some of the products in the showcase that relate to different technologies:

Kingfisher - Fishing Tackle

Kingfisher specializes in providing advanced equipment for aquaculture and mussel farming,

offering a range of custom-made solutions since 2011. From delimitation nets to beach seines and purse seines, they cater to farms of all sizes. Kingfisher's expertise includes seeding equipment and tailored netting systems designed to meet specific operational needs. It supports sustainable aquaculture practices through innovative net designs and efficient mussel farming equipment. Their custom solutions promote effective resource use while minimizing environmental impact, enabling the growth of sustainable aquaculture industries in Sweden and beyond.

CiYOU Bioreactor

CiYOU is a lab-scale bioreactor designed for flexible and controlled microorganism cultivation using Biorea's advanced fermentation technology. Equipped with airlift technology, it supports various metabolic pathways (heterotrophy, mixotrophy, autotrophy, anaeroby, and aeroby) and can cultivate microalgae, bacteria, fungi, yeast, and plant cells in a user-friendly environment. Their reactors are designed, manufactured, and assembled in Brittany, France, in collaboration with local partners for parts and electronics.

The Wave Field

It is an innovative floating cultivation and teaching platform, designed to bring marine sustainability and education to life. Launched in June 2020 at Kalvebod Bølge in Copenhagen, the Wave Field serves as a prototype for cultivating marine crops like mussels and seaweed, while also providing an interactive space for hands-on learning. This visionary project combines environmental innovation with community engagement, inspiring a deeper connection to our marine ecosystems.

Production Management Software

Rubisko provides production management software and data consultancy tailored to sustainable and emerging agriculture industries. Their platform combines standardized tools with industry-specific modules, such as seaweed and vertical farming, to enhance efficiency, traceability and decision-making. With a focus on scalability and seamless integration, Rubisko helps businesses leverage data for growth, sustainability, and reduced environmental impact.

Figure 3 Images from the examples of 4 product showcase (BlueBioMatch profiles) addressing technological needs in the blue bioeconomy sectors

Recommendations

- To address the diverse and regionally specific technological needs identified in this report, the development of regional Blue Tech Hubs or clusters could be an interesting approach. These hubs should serve as innovation accelerators, offering access to shared infrastructure, training programmes, technical assistance, and venture support. They should also be embedded within broader innovation ecosystems that include universities, industry partners, and regional authorities.
- Investment should be directed toward the establishment of open-access biorefineries designed for adaptability and circularity. These facilities would enable SMEs and early-stage innovators to pilot new processes and validate technologies in pre-commercial settings. Furthermore, targeted interregional demonstrator projects should be launched to pilot and test solutions to shared challenges, such as algae-based packaging materials, shell-based construction composites, or integrated aquaponic systems.
- Complementing these efforts, digital solutions should be promoted that enable traceability, environmental monitoring, and sustainability certification throughout marine value chains. A harmonised approach to data standards and interoperability protocols will be necessary to ensure the effectiveness and scalability of such systems.
- A tiered support system should be developed across Europe, where local hubs provide early-stage support and validation, while regional and transnational hubs offer scale-up and export-readiness assistance. This structure should be coupled with simplified access to public and private funding pools, bolstered by EU-wide recognition mechanisms that reward sustainability and innovation.

These recommendations offer a pathway to transform the European blue bioeconomy into a knowledge-driven, sustainable sector capable of delivering regional prosperity and global leadership in marine-based innovation.

Conclusion

This report consolidates a comprehensive set of findings from mapping exercises, regional interviews, and stakeholder engagements carried out under Work Package 4. It reveals critical infrastructure gaps, low technology readiness levels in key subsectors, and persistent barriers to innovation transfer.

Despite regional diversity in marine resources, industrial maturity, and policy frameworks, several recurrent technological needs have been identified across all BlueBioClusters regions. These include the lack of pilot and scale-up facilities, limited access to shared bioprocessing infrastructure, low uptake of digital and automation technologies, and weak interfaces between research and market actors. These limitations restrict the capacity of SMEs and startups to validate innovations, attract investment, and deploy market-ready solutions.

The transition toward a sustainable blue bioeconomy across Europe hinges on the ability to address region-specific technological needs while fostering cross-cutting solutions that support circularity, innovation, and coastal resilience. At the same time, the report demonstrates a growing momentum for transregional collaboration, supported by tools such as Blue Bio Match and local innovation clusters. Companies working in aquaculture, marine biotechnology, and biomass valorisation are increasingly aligned with sustainability objectives but require targeted support to achieve operational integration, product diversification, and market access.

The insights gathered here should serve to guide regional policy planning, research investments, and matchmaking strategies across the blue bioeconomy ecosystem. The findings reaffirm the need for shared infrastructure, coordinated innovation support, and interoperable digital tools. Addressing these challenges will be essential for scaling up blue bio-based solutions that align with the objectives of the EU Green Deal and contribute to resilient and inclusive blue growth.

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