Blue Bioeconomy Foresight Analysis

Blue bioeconomy strategic research and innovation agenda

Blue BIO COFUND

EFARO

INTRODUCTION

The Blue Bioeconomy COFUND (BlueBio) has as its main objective to establish a coordinated R&D funding scheme that will strengthen Europe's position in the Blue Bioeconomy. It addresses the need to future-proof the Blue Bioeconomy value chains of today to ensure its sustainable growth. The goal is to identify new, and improve existing ways of bringing bio-based products and services to the market and find new ways of creating value from the Blue Bioeconomy.

In order to guide this process, BlueBio developed a strategic research and innovation agenda. In this report we present the Foresight Analysis process and the resulting strategic research and innovation agenda for the Blue Bioeconomy.

Credits

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6 AREAS WITH RESEARCH AND INNOVATION NEEDS IN THE BLUE BIOECONOMY

A strategic research and innovation agenda is necessary to strengthen Europe's position in the Blue Bioeconomy. Through the method of scenario building, with stakeholders from the whole quadruple helix, hence industry, government, society and science, BlueBio presents a SRIA on the blue bioeconomy.

1 Blue Balance

The blue biosphere must be understood and tipping points for ecosystem services must be identified if we are to intensity utilisation of biomass. We must use new technologies to understand the effects of ecosystem manipulation and the land-sea interactions. Nature based solutions must be part of sustainable use.

2 Societal Balance

The interplay between the blue bioeconomy and society is essential. Trust, understanding, and social legitimacy must be present to develop regulations, management plans and markets.

3 Climate change

Climate change will influence aquatic ecosystems. The direct and indirect effects must be understood and modelled, both to manage the socio-ecological system and to adapt and mitigate impacts.

4 Technological innovation

There are numerous possibilities for the blue bioeconomy in technological innovation. Intelligent monitoring systems, genetic engineering, finding alternatives to antimicrobials, recirculating aquaculture systems, carbon capture, improvement of feed and food resources, and ensuring animal health and welfare are all important pieces of the puzzle.

5 Value chain development

The production cycle must be closed to truly future-proof the blue bioeconomy. We must optimise side-streams, minimise waste, understand the whole value chain ecosystem – both blue and green, and implement full-chain traceability.

6 Science for society

There is no impact of the research and innovation without uptake in society. We must understand how to promote links between science and decision making, improving education, empowering people, building capacity and promoting ocean literacy.

When you want to know how we build this agenda and which was the process we followed, go to page 6, The Foresight Process. When you want to dive straight into the SRIA, go to page 14, The Strategic Research and Innovation Agenda.

THE FORESIGHT PROCESS

BlueBio aimed to develop a strategic research and innovation agenda (SRIA) to bring bio-based products and services to the market and find new ways of creating value from the Blue Bioeconomy. There are many different forms of developing a SRIA. A often used concept is to build on existing research agendas and have representatives of the science community indicate which future issues need to be addressed. A wide variety of stakeholders must be included to have a properly strategic research agenda. In addition, under the current uncertain circumstances, characterised by innovation and rapid change, the use of scenario planning techniques is a useful tool to cope with complexity.

In the French approach of "la prospective", the underlying principal of prospective thinking is that the future is not part of a predetermined temporal continuity, but it can be deliberately created and modelled. For the development of the BlueBio SRIA we combined the methodology of Foresight with the use of Scenarios. We built on analyses and SRIAs in the marine value chain domains already created such as SCAR Foresight (2015), JPI Oceans Strategy Framework 2021-2025, Sustainable Blue Economy (2021), Sustainable Blue Economy Partnership SRIA (2021), BANOS SOP (2021), European Green Deal (2019), European Aquaculture Technology and Innovation Platform (EATIP) SRIA (2017), EMB Navigating the Future V (2017), ERA-MBT Roadmap (2016), 4th SCAR Foresight Exercise (2015), COFASP Foresight (2014).

A series of 4 workshops was held (3 with stakeholders and a 4th to present the findings to the BlueBio community) attended by a wide variety of stakeholders from science and research, industry, policy and the NGO community.

THE PROCESS

The process consists of 5 consecutive steps. Step 1, Define the System, involves describing the Blue Bioeconomy system that is going to be the focal point of our analysis. This consists of an overall Blue Bio Economy System, with parts belonging in the system and parts being outside of the system. And it includes a number of subsystems.

Step 2, Drivers, identifies drivers for each of the subsystems and the overall system. Drivers that determine the future (development) of the (sub)system. Each subsystem can be described by an array of different variables. Drivers are those variables that have a larger determining power of the development of the (sub)system than others.

Whereas in the original Foresight methodology the identified Drivers would be used to create Scenarios, noting the already vast amount of Scenario studies being available in the Blue Bio Economy, during this exercise it was decided to select a set of already identified scenarios and use these to determine the possible futures of the system we defined.

Confronting the system with the selected scenarios resulted in 4 possible future 'states' of our Blue Bioeconomy System. These 4 different states are 4 possible future Worlds, or in other words 4 pictures of how the future may look like. Although each of the these worlds are based on realistic assumptions and developments, the endeavour is, as much as possible, to create opposing views of the world. Because, in step 5, determining Research Needs, the goal is immersion into each of these 4 worlds in order to visualize and determine the research agenda in that specific world. If a certain research topic is identified in a number of these different worlds, it will be a safe bet that no matter what future developments may bring (or in what world we will end up) this is a topic that needs attention.

The time horizon has been set at 30 years from today in order to allow us to free ourselves from the developments of today and be open to all kinds of possible futures.

*Figure 1.
5 steps towards
a research agenda*

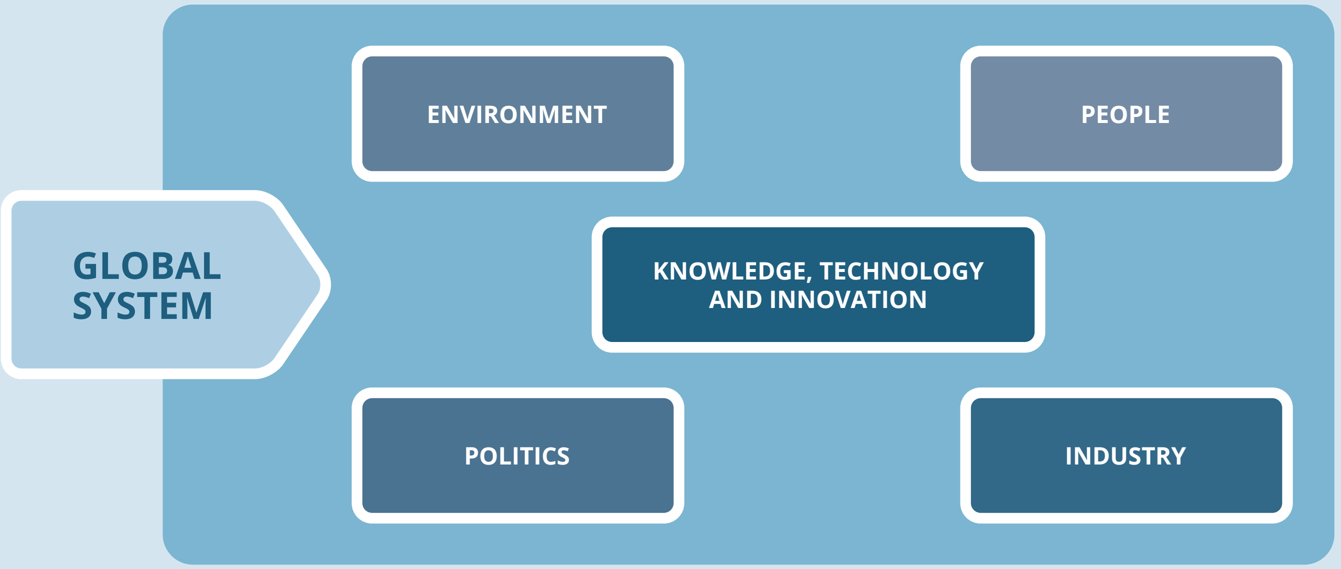


Figure 2.
The defined blue bioeconomy system, with sub-systems.

THE SYSTEM IS THE BLUE BIOECONOMY IN EUROPE

The system has the following subsystems:

- **GLOBAL SYSTEM**: global trends that are outside of our control and our direct Blue Bioeconomy in Europe, but do impact on it.
- **POLITICS:** this comprises all of the governance aspects of who is involved in the governance system, how does the system of decision-making operate and what is the ultimate result: policy.
- **ENVIRONMENT:** the natural system with its abiotic and biotic factors, ecological processes, biodiversity (e.g. species and genetics) ecosystem services and boundaries for human use.
- **PEOPLE:** the society and its changes within Europe and how these changes may affect the demands and needs related to the Blue Bioeconomy.
- **INDUSTRY:** all parties involved in the value chain based on the sustainable use of renewable aquatic resources. This includes producers (fisheries & aquaculture), processors (e.g., food, feed, bluebio-refineries) and sales (e.g., retailers, wholesalers) as well as other involved sectors (e.g. marketing, transport, energy, technology, finance).
- **KNOWLEDGE, TECHNOLOGY AND INNOVATION:** multi- & transdisciplinary research and its outcomes, merging theoretical & empirical knowledge to develop solutions (products, processes) which can be applied for addressing global challenges at local and regional scale.

THE DRIVERS

For each of the subsystems a number of drivers was identified. For a detailed description of each of the drivers you can read the final report which is available here: https://bluebioeconomy.eu/

TABLE 1. PRESENTATION OF DRIVERS IDENTIFIED IN EACH SYSTEM.

GLOBAL SYSTEM	Economic signature	Global politics	Global demography	Competition for resources			
POLITICS, POLICY AND GOVERNANCE	Political signature	Data availability & information	Ocean literacy	Value system	Legitimacy		
ENVIRONMENT	Use ((future) harvesting activities)	Pollution	Climate change				
PEOPLE	Demography	Wealth	Food security	Health			
KNOWLEDGE, INNOVATION AND TECHNOLOGY	Societal, industrial needs & demands	Policy research & innovation	Funding	Capacity building	Research capacity	Knowledge chain structure	Knowlegde creation
INDUSTRY	Value chain structure	Consumer demands	Value creation structure	License to operate	Finance & production costs		

SELECTING SCENARIOS[1]

Based on a wide selection of scenario studies in the Blue Bioeconomy domain, the following elements were selected:

- The Future of the Food Economy Scenarios[2] captures the point of view of the Food Industry. exploring possible scenarios in which the food industry would operate in a relatively near future (2030).
- The SCAR scenarios[3] focussing on the demand and supply of biomass under three scenarios.
- Add: stable/disruptive world and distribution of power.
- Add: stability vs. de-stability and sustainable vs. unsustainable.

[1] *The FEUFAR project (FP6 funded, 2007-2008) was the first foresight exercise in the field of fisheries and aquaculture developing a research agenda. The COFASP ERAnet (FP7, 2013-2017) developed a Strategic Research and Innovation Agenda covering fisheries and aquaculture and including the fish processing sector. Of recent date there are a number of activities developed addressing possible scenarios and developments related to the Blue Bioeconomy such as the JPI Oceans Strategy Framework 2021-2025, Sustainable Blue Economy (2021), Sustainable Blue Economy Partnership SRIA (2021), BANOS SOP (2021), European Green Deal (2019), European Aquaculture Technology and Innovation Platform (EATIP) SRIA (2017), ERA-MBT Roadmap (2016), 4th SCAR Foresight Exercise (2015), COFASP Foresight (2014).*
[2] *Cluster Ernährung und das Kompetenzzentrum für Ernährung (2017) The Future of the Food Economy.*
[3] *Kovacs et al. (2015). Sustainable Agriculture, Forestry and Fisheries in the Bioeconomy – A Challenge for Europe. 10.2777/179843.*

Subsystem	Driver	Blue Balance	Green Isolation	Grey	Dark
People	Demography	Balanced age structure and density distribution.	Aging European population. European borders are hot spots of conflict due to migration and protectionism.	Stable, but unbalanced towards older ages. Limited migration, just for labour needs.	High mobility, refugees moving towards the big cities. Life expectancy lowers in Europe.
	Wealth	Very limited poverty, relatively well distributed wealth across European societies, and across the world, still a discussion about the concentration of wealth to a few very rich people due to the huge markets created by digitalization and global trade.	Very unequal distribution. Top very rich; large population of (illegal) immigrants on low paid jobs.	Generally high but unbalanced; industry and technology are wealthy.	Most are poor, some individuals making fortunes (high risk, high gain).
	Health	Healthy people with healthy diets (globally).	Rich top is healthy. Large group with no access to health care, insurance is expensive.	Generally good (high life expectancy), but aging creates strong demands for functional food that is being covered by biotech, yet environmental issues create high healthy risks.	Low all over.
	Food security	Zero hunger.	No big issues.	In terms of provision, it is secured. For wealthy people safety is also secured. For a large portion of the population only provision is really secured.	Low all over, better in some resource-rich areas.

Figure 3. Illustration of the drivers of the sub-systems for each selected scenario.

THE FUTURE WORLDS

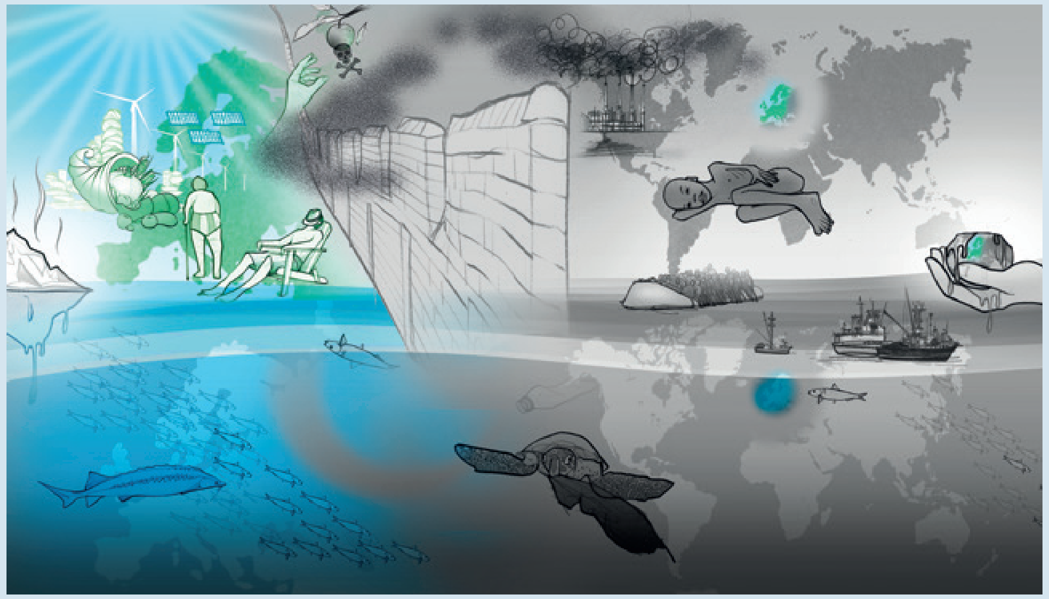
By using the selected scenarios and confronting the drivers of the sub-system with these scenarios, possible 'states' of each of the drivers were created. These in turn resulted in a state of the overall system, referred to as Future World.
In the figure above an example of how a subsystem (here: People) would look like under four different scenarios for each of its four drivers (Demography, Wealth, Health and Food Security). Ultimately, this resulted in four Future Worlds.

Blue Balance

People would be happy, healthy, wealthy and would have a good balance in their diet and enough of what they need. Industry would be thriving, creating value in a sustainable and responsible way with a lot of innovation. Knowledge would entail open science based on well-functioning funding of research resulting in many innovations. Biodiversity is high and well managed, resulting in a high supply of bioresources. There is zero-pollution and the climate is stable. There exists a stable political situation that is functioning well with an extensive distribution of power and a functioning democracy. Environmental changes and use of natural resources are managed well. Globally there is a balance of power, the world is peaceful and there is zero terror.

Green Isolation

After a few decades pushing for the realisation of the EU green deal objectives some important achievements were attained in terms of halting biodiversity loss, protecting our seas and oceans, increasing the opportunities for a thriving but protective bioeconomy this leading to high levels of employment, innovation and education standards as well as to high food quality and safety standards. However, Europe is losing weight in the global context because its standards are not followed globally. Major challenges are related to access to raw materials, which is getting more and more difficult, the effects of climate change continue to threaten the stability of the world and revealing the inefficiency of an isolated approach. The aging population is limiting the capacity of the system to operate: no young labour force available. As a result, inequality and polarisation of the society is putting tension on the system leading to a new cycle of instability.

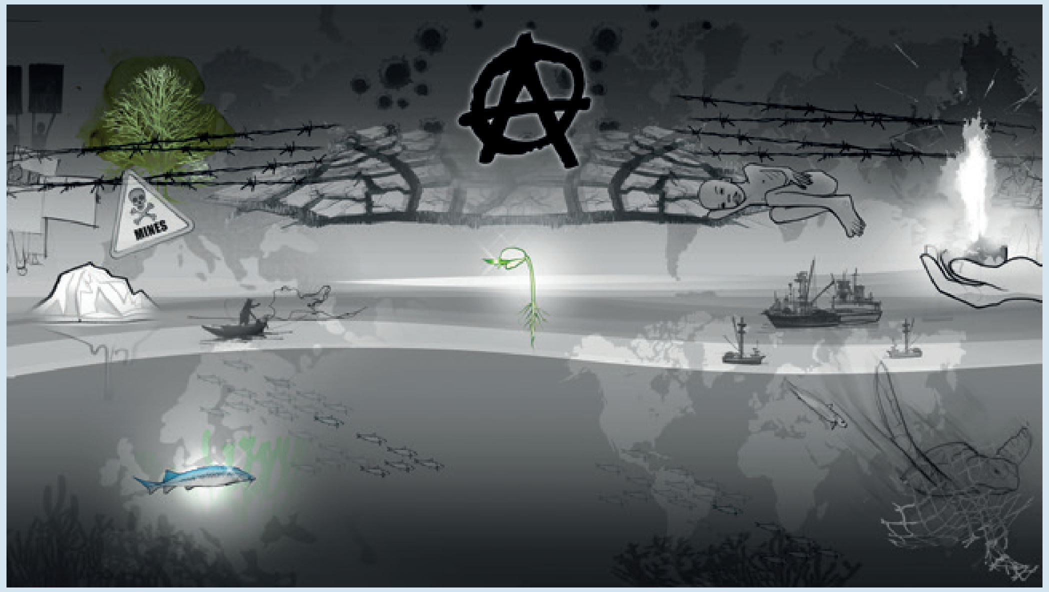


Dark World

It is a miserable dark world, with a lot of instability and no regulations at all. On a global scale no common policies exist and governments and UN have no impact on our system. International agreements are not followed or fulfilled. There is no coherent discission making.

International markets will collapse and with no international trading, production and consumption is local. As it is risky world, the industry is unwilling to invest. There are opportunities for investment but these come with high risks. There is no trust in decisionmakers or political institutions, there is conflict and revolution and high levels of protectionism in society. There is a lot of pressure on ecosystems on a local scale, as societies only trust their own local resources, There is no capacity for big developments on a grander scale. The population will stagnate and decrease and the economy will decrease, potentially taken the pressure off the environment.

There is no societal regulation for new technology. Everybody could develop what they think is good, there are no limits to research and innovation as such. An IP system does not exist. People will have poor health, there would be food scarcity, supply would be low, high level of demographic changes in society with a concentration of the populations living in the cities. Worldwide migration is pushed due to large areas with limited food availability and climate change.

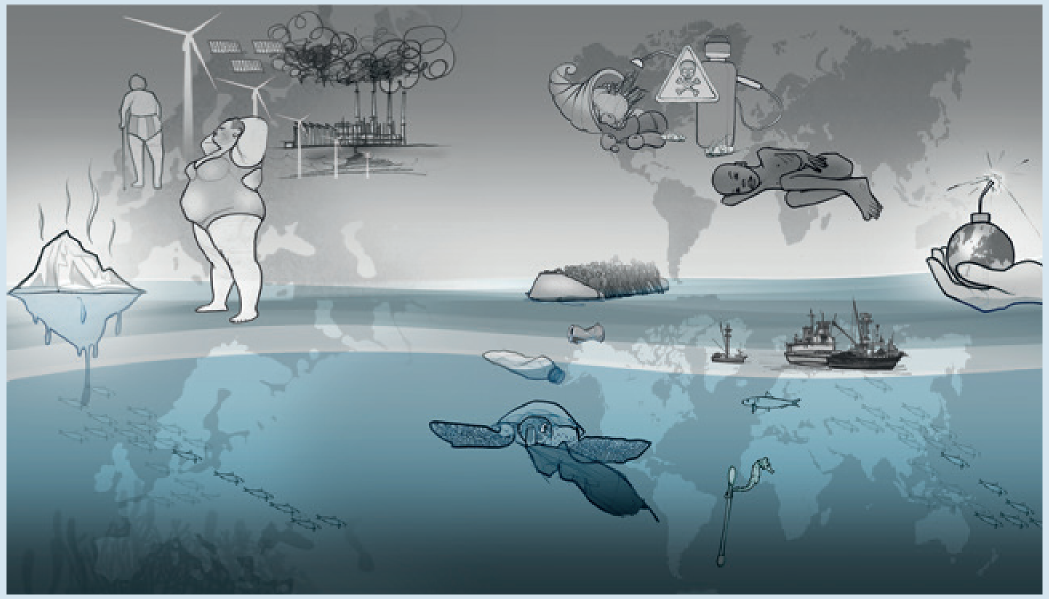


Grey Status Q

Our world is defined by multipower regions and still divided in developed and developing countries. Wars are due to competition over resources. There is political stability and a stable demography in developed countries. Developing countries are still unstable, but the age of people is also increasing. Innovation is very high and driven by industry. IP is in the hands of industry. The world is liberal and has low levels of regulation. Ecosystem services are not being taken into account in the economy - not internalised. People are healthy and wealth is in general high, but unequally distributed. The mindset is selfish with a short-term focus. The environment is highly polluted.

Climate Change (CC) is still impacting as well. Although greenhouse gases emissions have been reduced (due to scarcity of fuels of fossil origin, fuel industry has moved to more clean energy, yet not fully sustainable). However, this step was taken too late and the consequences of CC are high and impacting both environment and the economy. Migration of people has increased due to negative effect of climate change in some parts of the world. Use of natural resources is increasing but through innovation (e.g. precision farming, adding nutrients, pesticides) it is still possible to maintain adequate levels of production.

Europe's population is stable, wealthy, but with health issues (obesity issues) - people are getting old. We get novel foods, yet a lot of food sources are unsafe as a result of inadequate regulation. Only a portion of the population calls for better regulation, and a more sustainable use of resources.



THE STRATEGIC RESEARCH AND INNOVATION AGENDA

For each of the four worlds an inventory was made of the particular research and innovation needs and practices of that particular world. Based on this inventory the more generic SRIA was developed. Details of the analysis can be found in the report. Below you can find the SRIA. The SRIA covers six areas: Ecosystem balance, Societal balance, Climate Change, Technological Innovation, Value Chain Development and Science for Society.

Ecosystem Balance

The natural systems are under pressure due to increased population and human behavior. We need to find ways to secure our food production for the increasing human population and at the same time keep the aquatic ecosystems (the blue biosphere) healthy and to use the resources sustainably. We need to find the balance of utilizing resources and keeping healthy systems. It is a delicate, dynamic balance that requires adjustments following changes in nature. We need to develop, test and deploy sensors for real time measurement. We still need to understand the factors delivering the services - e.g. carbon sequestration.

Fully understanding the blue biosphere; the structure and organisms

In order to fully understand the blue biosphere we will have to:

- Map the aquatic microbiome and its connectivity in variation in time and space. Micro-organisms in the ocean play an important role in delivering ecosystem services e.g. carbon sequestration. Understanding microbiomes in coastal or confined systems may provide further insights into functions in the ecosystem as well as potential ecosystem services that can be further enhanced, e.g. denitrification or combating diseases.
- Improve the understanding of how microbiomes within and between ocean (aquatic) regions connect with and influence one another.
- Further understanding of food web interactions.
- There is a need to understand the Deep Ocean and the interaction between deep sea and top layers, coastal system and atmosphere.

Identifying ecological tipping points to maintain ecosystem services

The prerequisite for intensifying utilisation of biomass and ecosystem services from the blue biosphere is to ensure the systems are able to regenerate at the same speed of its utilisation. Natural variability may lead to changes in the regenerative capability of ecosystems. Identifying the tipping points where utilisation exceeds the capacity and key triggers of change are important to avoid systemic changes or collapse of systems.

Understanding the effects of ecosystem manipulation (Digital Twin)

The use of new technologies (AI, new sensor technology) is required to continuously update Digital Twins and prediction models, to better understand the functioning of the aquatic ecosystems. Our impact on the ecosystem requires detailed knowledge of physical, chemical and biological processes and their interaction as well as physiological boundaries of organisms.

- Develop common standards for data collection, handling and sharing, e.g. through standardisation of methods, calibrations and metadata.
- Improve capacities for the prediction of the future state of ocean health.

Understanding Blue/Green relation and land/sea interactions

The blue biosphere - the ocean and other aquatic systems – is not a separate islands, but is connected and interacting with the terrestrial systems and the atmosphere. To understand this relation there is a need to develop:

- Better knowledge (data, modelling) on how, and to what extent the health of the aquatic systems is influenced by the other systems and their use, and finding measures to minimize negative impacts.
- Finding ways to reconcile the different uses (spatial/temporal) sustainably (environmental-social-economic), reflected in Marine Spatial Planning.

How to use Nature Based Solutions in new ways of usage/production of resources whilst restoring the ecosystem?

Across the blue biosphere there is a need to improve the bridge between environmental observations, controlled experiments, data science and predictive modelling to create a deep and validated understanding of system interventions, the use of ecosystem services while ensuring robust ecosystems. This raises the question of minimal human impact as baseline for ecological restoration

Societal Balance

This research area concerns the interplay between society and a sustainable blue bioeconomy. Responsible developments within the blue bioeconomy depend on public trust, understanding and uptake of innovations, including novel foods, by all stakeholders and society. This is necessary to enable the proper implementation of technologies and thus to further develop and manage aquaculture and other Blue Bio industries in the European context and beyond. It is also necessary in order to enable an effective and socially legitimate regulation of production methods and multiple use of aquatic space, including the proper allocation of new production areas.

- What is the optimal allocation of space and resources between distinct users and uses, taking both ecological and societal concerns into consideration?
  - How should we develop and implement improved Marine Spatial Planning techniques, management and regulations?
  - What are the potential effects of new management systems, e.g. Marine Spatial Planning, on fisheries and other relevant interest groups?
  - How do we develop management schemes which are adaptive, and how do we redefine existing management systems (e.g. regulations of genetics, Marine Spatial Planning)?
- How do we develop socially legitimate and trustworthy regulations, including monitoring systems?
- How can we improve understanding of consumer preferences in order to develop new markets/demands or reintroduce traditional markets.
- How can we develop good/avoid skewed incentives (e.g. subsidies, taxes) in order to promote sustainable consumption?
- What is the potential recreational value of ecosystems and the effect of nature on human health – and how do we best manage aquatic ecosystems in such a way that they can be a competitive advantage for Europe?
- Possibilities for ecological compensation: need, possibilities, shortcomings, means, regulation/incentives.

Climate Change

It is established that the climate will change in the coming decades and this will have an impact on the aquatic ecosystems. There are direct impacts in terms of change in temperature and sea levels, and more indirect effects through the melting of ice caps that will change the salinity gradients of the ocean and may impact ocean currents. Extreme weather events will lead to changes in river flows and impact lakes and coastal areas.

Develop prediction models taking Carbon Capture into account

Carbon Capture will change the physical boundaries for life in the aquatic environment and will thus impact the possibilities for organisms to thrive. Larger Carbon Capture changes may lead to regime shifts, where the composition and structure of ecosystems fundamentally change. This will lead to changes to the ecosystem services we rely on.

Understanding Carbon Capture impact on the socio-ecological system (e.g., fish stocks, aquaculture)

Changes to the ecosystem and the ecosystem services provisioning will impact the social system. Fish stocks may change distribution and thus impact fisheries, that may have different local and regional socioeconomic impacts.

Identifying adaptation and mitigation of Carbon Capture impact

In order to adapt to climate change and mitigate the impacts of climate change there is a need to:

- Develop strategies to mitigate negative human impact on the (blue) biosphere at every scale, e.g. carbon sequestration, pollution control and remediation, and methane conversion.
- Finding measures to ensure the functioning of the aquatic ecosystems (resilience and adaptation) and the ecosystem services under the Carbon Capture.
- How we can mitigate the negative impacts on aquatic systems?
- How can aquatic systems assist in mitigating Carbon Capture and its impacts?

Technological Innovation

Development of monitoring of ecosystems, aquaculture production and resource extraction activities using remote sensors and Artificial Intelligence/ Machine Learning

Intelligent monitoring of ecosystems to establish a forecast system enabling dynamic knowledge based management of:

- Marine spatial planning.
- Countermeasures to adverse events.
- Early warning systems and automatic operation of aquaculture platforms.
- Aquaculture production optimisation.
- Safer and efficient marine logistics.
- Efficient and sustainable fisheries and harvesting.

Genetic engineering

Ethical application of genetic engineering as an alternative to traditional selective breeding to achieve:

- More sustainable production e.g. Sterile production organisms.
- New biofilters working at ambient temperatures allowing optimized production.
- Reduced environmental impact.
- Product with optimized traits such as composition e.g. Omega-3 fatty acids.
- Resistance against disease.
- Optimized production at ambient temperature.
- Reduced extraction of marine recourses for feed production.
- Better animal welfare e.g., organisms less susceptible to stress.

How to use carbon capture to produce food, feed and non-degradable deposition forms

Cultivation of photoautotrophic and chemoautotrophic organisms to capture carbon to produce biomass and energy carriers:

- Deep sea bioprospecting to find new organisms. genes and enzymes.
- More efficient reactors.
- Efficient large scale capture of atmospheric CO2.
- Use of side streams as nutrients for photoautotrophic and heterotrophic organisms.
- Responsible environmental engineering to increase carbon sequestration and system carrying capacity.

How to develop alternatives to antibiotics and hazardous chemicals

Alternatives to antibiotics and hazardous chemicals can be developed through:

- Development of new probiotics and functional feed.
- Development of new vaccines and other prophylactic measures.
- Less industrialized production systems – e.g., organic production.
- Development of new antimicrobial substances less prone to resistance development.

Development of recirculation systems for aquaculture on land and at sea

Recirculation systems for aquaculture production both at sea and on land can be further developed through:

- Development of closed sea water-based production recirculation systems.
- Development of new biofilters working at ambient temperatures allowing optimized production.
- Development of alternatives to biological nitrification.
- Commercial exploitation of biofilter biomass.
- "Closed loop" approaches for fully automated production.

How to detoxify feed/food resources?

In order to detoxify aquatic food and feed resources there is the need for:

- Development of detoxification processes and tools that do not compromise product quality.
- Better systems for continuous monitoring of levels of toxic substances.
- Better understanding and standardization of toxicity threshold values in feed and final product.

How to ensure animal welfare and health?

Animal welfare and health can be further developed through:

- More efficient production systems allowing reduced organism density.
- More animal friendly production systems with reduced stress.
- New vaccines and other prophylactic approaches to prevent infectious diseases.
- Better vaccine concepts with less side effects e.g., oral vaccines.
- New treatment concepts e.g. Phage therapy not involving use of antibiotics.
- More efficient prevention and treatment towards parasite infestation.
- Better understanding of the biology of production organisms.
- Better forecasting and prevention of adverse environmental impact on production.
- Noninvasive methods to monitor animal welfare.
- Individual monitoring and treatment.
- Humane killing of capture fish.

Value Chain development

How to make production cycles circular? How to optimize side streams and minimize waste?

Waste should not exist. Every process generates side streams. These side streams are used as resource for other products (food/feed/chemical/material/soil enhancer/energy), following the waste hierarchy[1]. Side streams are e.g.: by-products of fisheries and aquaculture processing, by-catch, effluents of aquaculture containing N and P, fish manure, dead fish.

- How to optimize the valorization of side streams using a biorefinery approach?
- How can N and P be re-used for cultivation purposes (aquaculture and agriculture), including nature-based solutions for example carbon capture solutions?
- How to reduce or exchange the use of plastics and other materials in fisheries and aquaculture by novel materials?

How to implement full value chain traceability?

Full-chain traceability is traceability from brood stock to adult fish in aquaculture, location of fishing grounds, origin of fish meal, supply chain, processing. Traceability is necessary to demonstrate the production processes and hence demonstrate e.g., sustainability and product quality.

- Need a reliable and trustworthy system for traceability for consumers, authorities and companies.
- How to use traceability to demonstrate sustainability?
- How to demonstrate sustainability of process and product?

How to generate a sustainable value chain ecosystem; co-existing value chains. And understanding Blue/Green relation and land/sea interactions of production systems

There is a competition for space both on land and at sea, particularly in coastal areas where different maritime activities co-exist. There is a need for optimization of side streams from agriculture being used for aquaculture or fisheries and vice versa. This will generate more efficient agri- and aquaculture (a better land/sea interaction).

- How to optimise the use of the ocean space for food production (fisheries, aquaculture), energy production, tourism considering a multi-use approach?
- How to optimise the interaction between land based and ocean based production systems to increase sustainability and production efficiency?

[1] Prevention, Re-use, Recycling, Recovery, Disposal

Identifying new species for food production robustness (e.g. risk reduction as well as production efficiency) considering low and multi trophic aquaculture. And developing novel foods and sustainable healthy/functional food/food supplements

Diversification and increase in number of species being used as well as aquatic products will unlock the potential of aquatic bioresources for healthy and functional food products and ingredients. This increases the resilience of the aquaculture system both on production and product side. Introduction of lower trophic species can increase the biomass production efficiency.

- There is a need for the identification of the best suited species for aquaculture and fisheries. How to deal with the ecosystem consequences of harvesting or cultivation?
- New species (including microbiomes) will open the way for new (healthy, more functional) products (food/feed/chemical/pharmaceutical/material) by processing, also generating new side streams.
- How can bioprospecting reveal the opportunities of new products?

Science for Society

Whereas under social balance we mean balance within society, between the different social components and society with its environment, under science for society we refer to how science is used and engaged by society. Research in the blue bioeconomy should include processes to ensure the proper uptake of this research in industry and society in order to improve education, empowering people, build capacity and promote ocean literacy in Europe and on a global scale. This research area promotes the interlinkage between science and decision making (politics), focusing on transdisciplinary research involving stakeholders, and capacity building to enable an efficient use of science in policymaking and management systems (science for policy).

- How may we foresee and address unintended adverse and beneficial effects of new technologies/new interventions in systems (natural and social)? (for example responsible use of biotechnology, genetic engineering).
- How do we develop a good relation between education, fundamental research, applied research and technology, and end-users? (For example the development of new foods, use of low-trophic aquatic food).
- How should researchers be trained in order to communicate their results in an understandable and transparent way and interact efficiently with policymakers, other stakeholders, and the public?
- How do we enable the engagement and active contribution of stakeholders into the development and implementation of the Blue Bio research agenda and programmes?
- How do we enable the uptake of citizen science data into Blue Bioeconomy research and innovation?
- How do we implement ecosystem-based management to optimize ecosystem services, including production?
- How can the One Health concept (interaction between human, animal, and environmental health) be operationalized, in order to improve food safety, animal welfare and to avoid global health crises, including pandemics, and to enable increased production from aquaculture.

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