HORIZON SCAN

OCEAN TECHNOLOGIES FOR A BETTER WORLD

GREEN INNOVATION GROUP A/S

THE VELUX FOUNDATIONS
VILLUM FONDEN VELUX FONDEN

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FOREWORD

Predicting the future is hard work. Not only do you have to try and do the impossible, you are also faced with the challenge of not losing face as your predictions fail to come true. With BIFROST, GREEN INNOVATION GROUP has been mapping and tracking the frontiers of impact innovation for years. This extensive data puts us in a position where we can take an educated guess at the future lying ahead of us, when we try to understand the challenges of the coming years.

This horizon scan sets out to equip you to face the future of ocean technology - what are the technologies, trends, and risks that you have to factor in when you are making decisions and setting your strategy for the years ahead?

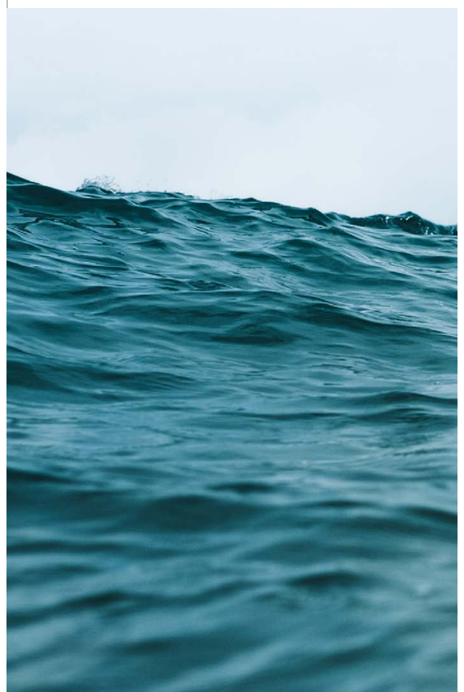
There is a reason why anecdotes and examples are popular tools in communication; it is easier for us to relate to concrete cases than abstract technological concepts. This is why most trends, predictions, and observations in this horizon scan are complemented by real-life examples of first-movers that are implementing the technology of tomorrow, today.

Attempting to arm you with knowledge and insights on technology trends, we have created technology maps that show what is going on in which fields to provide you with a visual tool to orient yourself in the fast-changing underwater jungle of 121 ocean innovations.

Each technology subsection holds our predictions for the next 5 and 20 years of global development, connected to cases that are already deployed around the world. For these predictions, we are standing on the shoulders of a vast knowledge community, our network of more than 50 ocean expert contributors.

We believe that there are reasons to be optimistic for the future of our planet, considering the wide array of technological developments that address the issues we are facing - the question remains, will we be able to act fast and intelligent enough to prevent ecological destruction and transition to a regenerative society. Hopefully, this horizon scan will provide you with the tools to take action today.

Frederik van Deurs,
CEO, GREEN INNOVATION GROUP A/S



EXECUTIVE SUMMARY

Just like the oceans of this world are ultimately one and the same, the issues facing marine bio-economies are interconnected. Every climate report unveils new escalating catastrophes, mounting on our shores, and in the unexplored depths of our oceans - with brightly colored plastics comprising only the tip of the iceberg.

Meanwhile, marine bio-economies continue to hold untold resources and opportunities for cultural, ecological, and financial growth. News of promising technological advancements is sprouting across sectors, providing hope that new tools will enable the sustainably balanced utilization and restoration of our oceans.

The innovations of tomorrow largely originate in the fluctuating ecosystem of startups, but they are most likely to be implemented and scaled through established industry players. This horizon scan presents a systematic exploration of the landscape of innovations within sustainable ocean technologies. As such this horizon scan provides the necessary context for future engagement with the developments and trends in this field.

To facilitate the acceleration of sustainable innovation and impact, GREEN INNOVATION GROUP presents an analysis of the conditions for blue startups in Europe and Denmark in particular. In this process, we identify four obstacles typically faced by blue startups that are in contrast to land-based innovators:

- No existing infrastructure
- Reliance on hardware solutions
- Hostility of saline environments
- Global dispersion of impact

In a multi-layered mapping, 121 relevant innovation cases have been identified, organized according to:

a) Area of application (discerning between opportunities and issues addressed)
b) Technology types employed
c) Geographical representation

For each area of application, we present a qualitative trend analysis exploring predictions on a 5 to 20 year timeline. In addition to outlining specific developments in each field, the following meta-trends were identified:

- Public and private action on sustainability is partly driven by visualized knowledge, hence the boom in awareness of plastic pollution.
- Proliferation of sensors and IoT technology will revolutionize our level of insight, the first step in scaling and visualizing knowledge of marine environments. The extent and accessibility of these real-time maps will be compounded by big data, cloud computing, and blockchain.
- Automated subsurface vehicles will be the solution to the extreme bottleneck of human resources in underwater interventions. This will let sustainable solutions scale globally.
- Innovations that directly accelerates the restoration of damaged and vulnerable marine ecosystems are few and far between, most of them nested in academic research. Consistent support and incentivization is needed to lift regenerative technologies from research to marketable and scalable solutions. Until then, widespread conservation is the only avenue to sustainable blue bio-economies.

For each group of technological innovations, GREEN INNOVATION GROUP provides predictive scenarios in terms of potential positive environmental impact. These scenarios are described in ways that let decision makers and other readers infer the potential role of their own activities and products in the process of actualizing these sustainable futures.

Ultimately, the analytical points of this horizon scan are synthesized in a collection of in-depth case perspectives - looking at their relevance to Danish marine environments, how each innovation can potentially shape the future, and the barriers to growth according to each startup.

This horizon scan demonstrates the importance of sustainable innovation for marine bio-economies. It also provides a full overview of the current landscape of innovation in the field. Furthermore, the multi-perspective predictive scenarios constitute the basis for leadership and impact innovation alike. The time for action is now.

01

INTRODUCTION

INTRODUCTION

Denmark is historically closely connected to the sea. When combined, we have longer coastlines than India, and the sea has defined our nation both geopolitically, culturally, and commercially. The so-called Blue Industries employ around 100,000 Danes, and connect the country with global markets and diplomacy.[1] However, the sustainability of marine environments and resources is threatened across the globe. Climate change, plastic pollution, and overfishing are but a few of the challenges faced by blue bio-economies. These challenges are complex in every sense of the word, spanning multiple sectors, continents, and with outcomes reaching far into the future.

At the same time, the oceans cover 71% of the planet's surface and still hold vast unexplored resources and opportunities for cultural and economic growth. New innovations of the digital age can empower this blue growth and simultaneously regenerate vulnerable and exploited marine environments. In this respect, Denmark acts as a microcosm of global problematiques, as well as a laboratory for the concerted efforts to meet the challenges of the future.

The technological solutions of today hold not only the potential to solve many of the issues that need to be addressed but also a great potential for utilizing the oceans' vast resources. If the seas of Denmark are to form the basis for a sustainable and robust marine bio-economy going forward, being at the forefront of these and future sustainable technologies is a must. Thus, the aim of this horizon scan is to map the current status of ocean technologies and uncover overarching trends within this space as well as assess the potential and scalability of these technologies so as to illuminate the direction that this field is moving in and on this basis inform decision making.

HORIZON SCANNING

More specifically, horizon scanning means systematically exploring the landscape of innovation in order to build an image of the current context and the pace of change. This image enables an identification of potential opportunities and challenges, as well as trends that can inform decision making. Thus, horizon scanning involves investigating novel and sometimes unusual innovations that seek to solve the current issues as well as exploring the possible synergies and intersecting applicability of these innovative solutions. The systematic explorations form the basis for qualified predictive scenarios, like the ones presented in this report, that are essential to innovation and strategic decision making. The purpose of horizon scanning is thus not about getting to a point of absolute certainty, but about being able to approach uncertainty in an informed and competent manner. That is the closest we can get to knowing what the future will bring.

SCOPE OF REPORT

The aim of this horizon scan is to outline the global trends within blue innovation in order to support public and private actors in efficiently navigating the future of this field. This entails a thorough exploration of central opportunities and challenges related to marine ecosystems, and mapping out the current and developing innovations for each of them respectively. Any new technologies must have direct or indirect positive environmental impacts in order to maintain relevance going forward. As such, this horizon scan of ocean technologies also presents various scenarios for positive effects, taking into account the possible synergies of promising technologies.

The basis for the present analysis is GREEN INNOVATION GROUP's year-long experience with multimethod knowledge generation - combining quantitative data on more than 4000 greentech startups with thick data that incorporates anthropological analyses of the motivations, conditions, and trajectories of numerous actors in the field.

THE REPORT CONTAINS THE FOLLOWING SECTIONS

- A thematic contextualization of the central issues pertaining to sustainable blue bio-economies, linking Danish and global circumstances.
- A mapping of the Danish ecosystem for startups in the field of sustainability in general and ocean technologies in particular.
- A multi-layered mapping of the specific innovation cases relevant to the future of blue bio-economies.
- A qualitative analysis of key trends and challenges within each area of interest.
- A set of predictive scenarios gauging the potential for positive environmental impact for each technology type assessed in this horizon scan.
- A thorough investigation of 7 key cases that represent key innovations within ocean technologies, including a look at possible synergies with other technologies as well as tentative predictions on a 5 and 20 year timeline.
- A summary and conclusion to the report for actors looking to support ocean technologies for a better world.
- An appendix containing a brief description of the methodological approach of this report, along with definitions of key concepts necessary for understanding the field.

02

BACKGROUND

BACKGROUND

GLOBAL CHALLENGES

Just like the oceans of the world are ultimately one and the same, the issues facing the blue bio-economies are interconnected. An innocuous temperature increase of 0.1 centigrade per decade in surface waters has lead to rising sea-levels (1mm per year), a 20% reduction in phytoplankton affecting all levels of marine food chains, more extreme weather, and increased coastal erosion - ultimately threatening human infrastructure and food security.[2] Likewise, tiny increases in ocean acidity have devastating effects on marine life and the resilience of blue ecosystems.[3]

Deterioration of coral reefs is threatening the diversity of marine life, supporting 25% of all marine species on the planet while only covering 0.1% of the area of the ocean. Commonly, coral reefs are associated with warmer climates, but in recent years scientists have discovered cold water coral reefs off the coast of Norway, and in Danish controlled waters between Iceland and Greenland.[4]

Several threats to marine bio-economies are direct effects of human practices and mismanagement. Images of plastic pollution have virtually visited every screen in recent years, but many similar environmental disasters are currently unfolding and escalating. Destructive fishing methods, increased ecosystem pressure from a growing shipping industry, drifting ghost nets, untreated industrial and urban waste water being discharged into rivers and oceans, the list goes on. All of these practices have compounding effects on marine bio-economies. These effects are so scary precisely because they are global - reaching across regional borders, industrial sectors, societal categories, and scientific fields. A failure to protect the Scandinavian bio-economy will reverberate in the Pacific, and vice versa.

However, the immense complexity of these issues is not an excuse to abdicate responsibility and initiative. Rather, it is an opportunity to innovate and collaborate on a scale unseen in human history. Through the newest technological developments, solutions are on the horizon that have the potential to scale across the aforementioned borders, regenerate damaged bio-economies, and generate valuable societal and commercial assets. This report presents a look at those technologies. In doing so, special attention is paid to a dual criteria: innovations of the future should scale globally, while being integrated locally.

A DANISH MICROCOSM

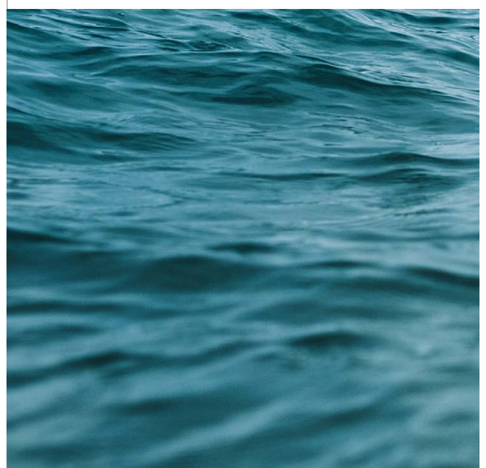
The challenges facing global marine environments only become clearer when focusing on the Danish context. Accumulation of plastic pollution has escaped public attention, but municipalities of the west coast collect around 1000 tons of waste on the shores every year.[5] The production processes of most industries have severe consequences for marine ecosystems - a cost that is rarely accounted for by industries themselves and instead left to taxpayers, voiceless marine species, and the coming generations.

In Denmark, emission and buildup of nitrogen and phosphor, primarily through agricultural waste, constitute the primary danger to marine health, with only 5% of Danish coastal areas achieving the ‘healthy environment’ designation.[6] Around 15% of global seaborne trade pass through the Baltic Sea, with largely unknown consequences for marine ecosystems.[7] Almost half of danish fish stocks are exposed to overfishing, approximately 40% in the Baltic Sea and 45% in the North Sea.[8]

In order to develop a more sustainable blue bio-economy in Denmark, an effort is needed on two fronts. On one hand, consistent and ambitious regulation is needed from public decision makers, a field that has been enveloped by scandals and misconduct for more than a decade.[9] Governmental plans of action are currently balancing protection of marine environments with facilitating growth in blue industries and maritime infrastructure (offshore wind- and fish-farms),[10] but the plans have yet to prove efficient in supporting healthy marine ecosystems.

On the other hand, a steady focus on innovation is needed within the industries themselves. Both in regards to sustainably optimizing specific processes, but also in a search of breakthroughs in the fundamental dynamics of each industry. Private actors currently recognize this as an area for CSR-profiling,[11] but are often more focused on general environmental and social efforts, rather than specifically protecting marine environments. This report hopefully illustrates that in the realm of private actors, innovation is largely found in independent and flexible startups, while their impact is largely consolidated through established industry players.

The ubiquity of Danish coastlines belies the complexity of balancing marine restoration, sustainable resource use, societal and commercial interests. Should we as a nation achieve that balance, a healthy marine bio-economy could prove a sturdy and enriching backdrop to flourishing developments in both environmental, cultural, and financial terms. Clearly that balance is not a fixed end-goal that we can point to in a statistic or a report. Rather it is the complex sum of our best knowledge of marine ecosystems coupled with the best efforts of lawmakers and industrial actors, as well as the general population. Efforts that take into account the inescapable connections to global blue bio-economies that are largely ignored by media and stakeholders.

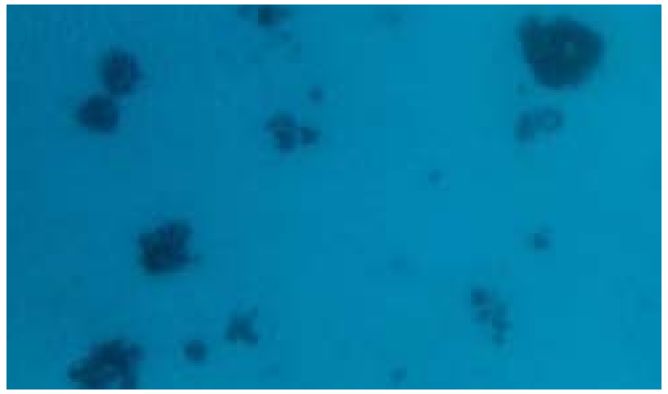


Currently, public opinion is primarily focused on conservation and protection of marine environments,[12] but with a considerable momentum in volunteering, driven by the Danish tradition of voluntary service and large parts of the population living in coastal areas.[13] Through the cases presented later, it will be demonstrated how specific technologies can synergize with the aims and trends of both public and private actors.

In Denmark, as in most other countries, demand is steadily increasing for marine resources and thus, the pressure continues to mount on vulnerable ecosystems.[14] If this growing demand is coupled with strong regulation from public actors and strong principles of sustainability by private actors, the focus on marine resources could lead to the proliferation of balanced solutions and protection of marine ecosystems.

In actuality, the Danish blue bio-economy also suggests considerable potential, especially within biotechnologies (via bio-refineries), AI or cloud-based platforms, and spearheading regenerative solutions. More than 400 different species of macroalgae, commonly called seaweed, grow in Danish waters. As the later cases will illustrate, this is a resource with underutilized potential, despite its suitability for e.g. sustainable energy production, pharmaceuticals, and food production.

Other industries with significant ecological footprints stand to benefit from innovations in the area, like transportation and shipping. Research from Aalborg University predicts a fourfold increase in European biogas production by 2030, thereby allowing at least 20% of the transport sector to operate on green fuels.[15] Biogas does not have the same storage limits as is the case with solar and wind powers, and maritime resources like seaweed, fish waste, and plastic waste are all suitable for the production of biogas. To actualize these cross-sector potentials, a tight collaboration is needed between innovative start-ups and established stakeholders with their own priorities and agendas.



OCEANIC POTENTIAL

When looking at ocean resources and the potential for growth and innovation, the public discourse is marred by dystopian outlooks on overfishing and harmful mistreatment of fragile marine environments. While these issues are serious in both scale and consequence, in actuality the oceans contain numerous avenues to bountiful resources. Benefitting from these resources need not be a detriment to marine ecosystems. On the contrary, if the development of blue industries is based on internationally recognized principles of sustainability, making use of the newest developments in regenerative technologies, this exploration of unaccessed resources can directly benefit the oceans, as well as businesses in the field.

Recent reports point to potential benefits in areas that are commonly overlooked: bycatch, fishing of current non-commercial species, harvesting or farming of algae and seaweed, even waste materials like plastic and sewage. These innocuous elements can be used directly or via bio-refineries in various aspects of food production,

animal feed, consumer goods such as cosmetics and textiles, and for developing of enzymes, antibiotics, and other medicinal products.[16] As demonstrated by the innovation cases in section PERSPECTIVES VIA SELECT BLUE STARTUP CASES, there is also considerable potential in combining digitally scaling technologies with upcycling dynamics. We thus point to ways in which industries and practices that are currently taxing the blue ecosystems, can gradually be transformed into a force regenerating the vulnerable bio-economies.

Overall, the development and application of next-generation digital technologies point to a global transformation of blue industries, be it through robotics and autonomous vessels, decentralized networks of sensors, utilization of satellite data, AI, IoT, or by creating detailed maps of different species and marine conditions, monitoring overfishing, chemical emissions, removing drifting fishing nets, the list continues.[17] Unique dynamics of marine ecosystems and lifeforms also have potential to jump scientific endeavours in the fields of biotechnology. It is the main aim of this report to outline the potential of these unexplored applications, and in particular to venture qualified predictions for the synergies between these technologies - digital and otherwise.

03

MAPPING OF THE DANISH ECOSYSTEM FOR BLUE INNOVATION

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THE STARTUP ECOSYSTEM

The majority of all maritime vessels carry Danish technology, and companies in this sector largely maintain a competitive advantage through a high degree of innovation and technological advantages.[18] It is through continual technological development that the solutions to the grave challenges faced by blue bio-economies are to be found. It is well established that a considerable part of innovations in a given field originate in flexible startups.[19] As such, it is worthwhile to pay attention to the conditions these emerging and growing companies face in developing tomorrow's solutions. Considering the extreme mobility, speed of international communication, and competitiveness of the global market, small differences in national or regional circumstances can significantly impact the viability of innovations from that area.

GREEN INNOVATION GROUP defines a startup ecosystem as a network of players that exists within and around a specific grouping of companies. Ecosystem in this report is used as a determining factor for having successful green startups, and the report evaluates the ecosystem based on its access to entrepreneur networks, network generating events and visibility for startups, access to legal and administrative guidance, access to potential clients, and access to risk willing capital.

In most respects the innovators of sustainable ocean technologies develop and operate in the same ways as other green technology companies. In order to provide a wider representation of developmental trajectories for sustainable innovation, the present analysis looks at all greentech companies available through BIFROST, for explanation see APPENDIX. This provides a clear picture of the conditions for ocean technology startups, while keeping the wider context of national differences and sector diversity intact.

A couple of exceptions should be noted with respect to ocean technology startups compared to land-based innovators:

NO EXISTING INFRASTRUCTURE

99% of European startups present solutions with an online component, and the vast majority work with primarily digital innovations.[20] These technologies scale well by interfacing with a digital infrastructure already in place (the internet, smartphones, desktops, etc). Such an infrastructure is not and will never be in place for ocean bio-economies. While innovations can target humans that interface with marine environments, the digital world, and thus much of the innovation space, is in most ways a human world. Marine ecosystems on the other hand, are markedly analogue.

RELIANCE ON PHYSICAL DEVICES

Getting something to work in or around the oceans usually entails developing physical products, or at the very least utilizing matter from the oceans in your product development. Moreover, sustainable innovations in this space must adhere to stricter principles of durability and seamless integration, since the marine ecosystems are tough on human equipment, and simultaneously vulnerable to destructive interference. Although this has not yet been the subject of major systematic inquiry, these two factors undoubtedly put a steeper learning curve and higher barrier of entry on startups engaging with blue bio-economies.

HOSTILE ENVIRONMENT

On a very basic level, humans interact differently with oceans than we do with environments above the surface. Since we can neither breathe, see, nor move freely underwater, the Deep is traditionally considered foreign territory to human cultures. We expect things to disappear in the oceans, and thus historically have dumped excessive amounts of waste. The three-dimensionality of the oceans makes it hard for humans to relate to the scale of ocean ecosystems and thus also to the effects we have on them and vice versa. That humans have only explored 5% of the global oceans,[21] while they in turn constitute 90% of the life-sustaining biosphere of our planet, are incomprehensible facts to most. For the ocean and coastal waters of the United States, only about 35% has been mapped with modern methods such as sonar technology.[22]

INTERCONNECTED ENVIRONMENTS

Speaking of scale, the previously mentioned interconnectedness of marine environments present a challenge to human interventions. We are used to measuring clear-cut effects on isolated environments, be they biological, social or financial. In the oceans, effects dissipate across national and regional borders. Likewise, disturbing factors and mismanagement of neighbouring marine environments can have devastating effects e.g. on efforts to restore specific ecosystems.

DIFFERENCES BETWEEN THE DANISH AND EUROPEAN ECOSYSTEMS

The ecosystem for green innovation in Denmark is characterized by a handful of differences from other European countries, which this section will cover.

01

The support and initial financial acceleration of startups in Denmark is based on a strong core of initiatives, grants, and competitions funded by the state or EU, through philanthropy or university environments. Angel investors and venture capital funds play a smaller role in Denmark than other European countries, when looking exclusively at green startups. The Danish government set aside a fond of EUR130 million for research in AI and Climate/Environment in May 2019.[23]

02

Danish startups present lower lifetime and monthly revenue numbers, even when comparing just to other scandinavian startups. This runs counter to the steep costs to initial development in ocean technologies.

03

Danish startups generally have a lower target for funding rounds. Furthermore, the gap between target investments and actual investments received is larger than other European startup ecosystems. Again, ocean technology companies usually have longer periods before products are market-ready, which in turn necessitates greater A-round investments.

04

Entrepreneurship is less culturally ingrained in Denmark than other European countries. For example, only 3% of Danes want to start their own company, while that number is 34% in France.[24]

Writer and owner of Nordic Web, Neil Murray, sums it up like this:

"... one of the biggest challenges in Denmark is the lack of early-stage investors who are able to look far ahead. Greentech startups typically tackle big problems or obstacles, so it may take some time before you see progress and traction. So, if you want to raise money, it is vital to bring investors on board who can be patient and support the visions in the long run, instead of investors who are destroying it [the long-term vision] by focusing on short time reimbursements."

According to Adam Hillestrøm, CEO of Dacofi (a Danish green startup with a new energy efficient method of filtering liquids), software-based startups have easier access to soft funding than hardware-based startups. Since soft funding is such a big part of the Danish startup ecosystem, this could explain why few Danish startup dive into innovation of blue hardware. In order to balance out this discrepancy, public and soft fund actors could focus their support on the initiatives lifting ideas from the universities into the market.

Bjarne Henning Jensen, Partner in Energy & Cleantech expands:

"The reason why green startups are experiencing adversity is partly because their green competitive advantage is not really taken into account [by customers] when they are compared to conventional solutions. The green components of a product/solution are only seen as add-ons without extra payment."

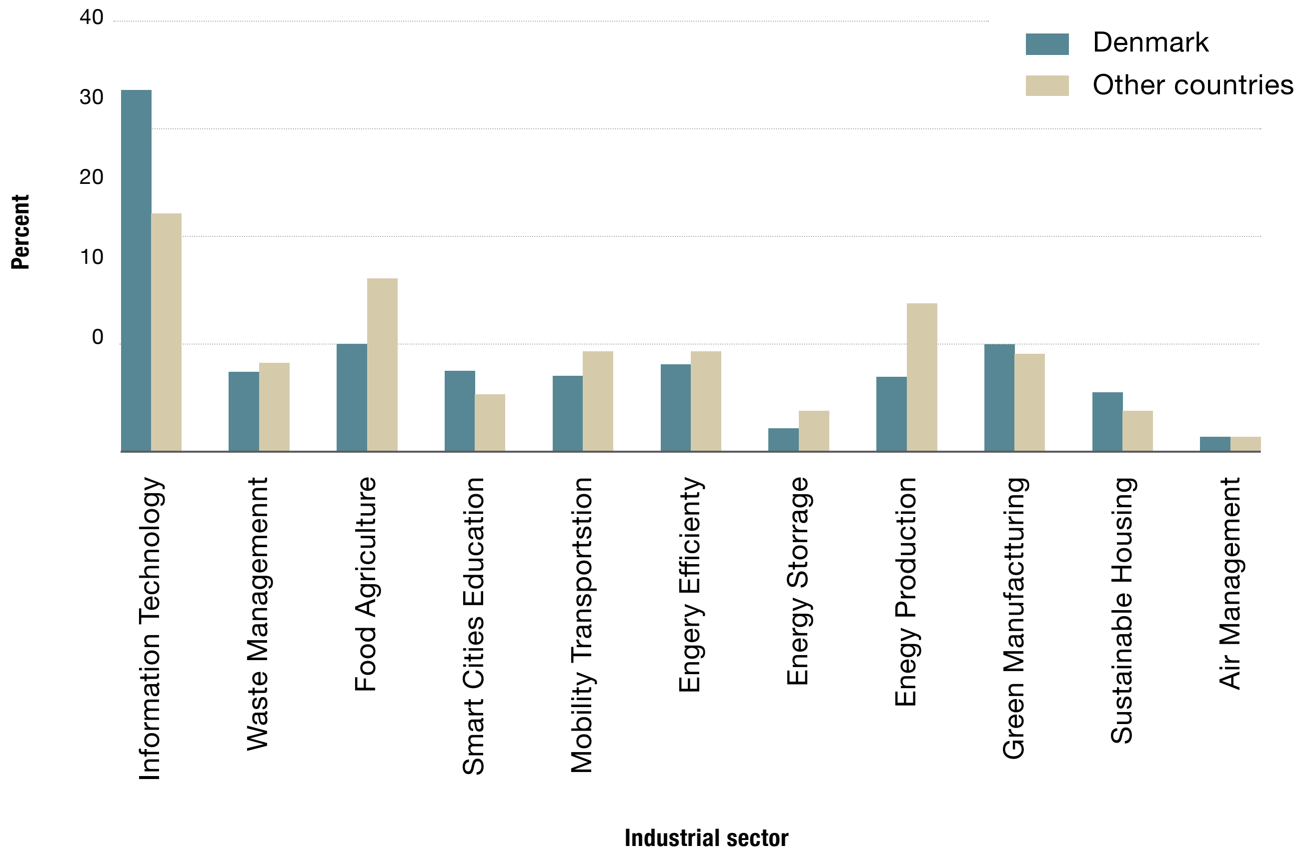
Currently, most industry backed innovation is focused on existing industries like shipping and offshore wind and oil. Truly sustainable innovation and development of regenerative technologies require startups and investors alike to understand and embrace the complicated interdisciplinary and cross-sectorial nature of blue bio-economies.

ECOSYSTEM GOING FORWARD

An innovation has 1700 times higher likelihood of being adopted by the market, if it is developed and marketed within the infrastructure of established companies.[25] This further stresses the need for tighter integration between startup innovators and established industry players, which would benefit the larger corporations as well. To this end, easily accessible advisory intermediates and qualified scouting, like the BIFROST platform, facilitates such a move.

Of the Danish startups analyzed by GREEN INNOVATION GROUP, 30% work specifically with information technology, a portion significantly higher than the EU average of 20%, see graph below. As will be expanded upon in the **BLUE TECHNOLOGY TRENDS** section, this will currently mean fewer Danish ocean technology startups. However, it provides an opportunity for Danish innovation to play a key role in scaling sustainable blue technologies, once the field becomes more saturated with data-generating sensors and AI-based analysis.

In order to seize this opportunity, which might not reach fruition until 10 to 20 years from now, innovators and investors alike must be aware of the long-term trends within blue bio-economies. These trends are not likely to be visible through current standardized market research, since a significant part of the potential value generated is not taken into account by today's metrics.



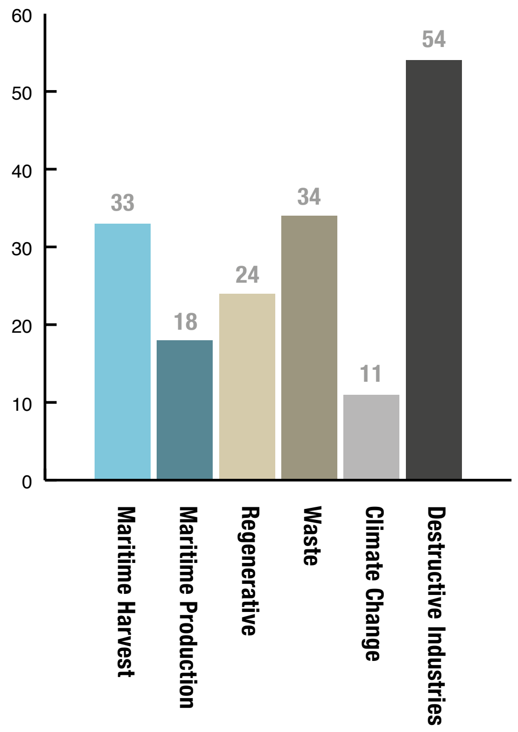
04

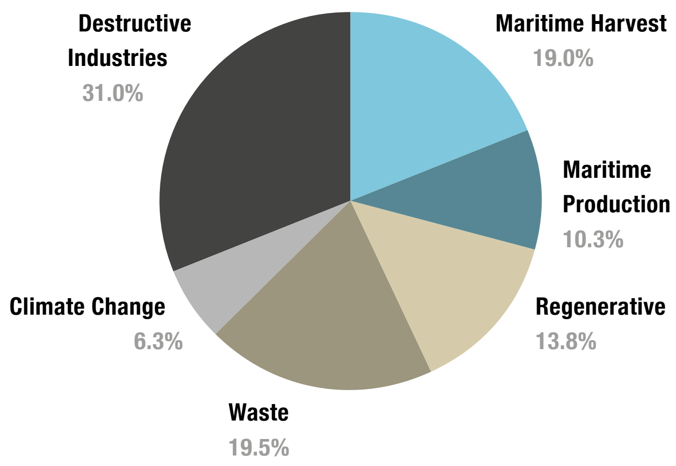
MAPPING OF BLUE TECHNOLOGY INNOVATIONS

MAPPING OF BLUE TECHNOLOGY INNOVATIONS

In the mapping of ocean technologies with potential for positive environmental impact, 121 relevant innovation cases have been identified partly from our existing portfolio of around 4000 green startups, partly from additional research. The companies apply a wide range of technologies and work within and across several sectors. As frontrunners of innovation, they are inherently interdisciplinary, organizationally flexible, and hard to categorize in sectors. However, creating an overview of the current and developing technologies within the blue innovation space necessitates a set of meaningful groupings of the innovations in question. Thus, several layered maps of the analyzed startup ecosystem have been made - grouped by area of application, technology types, and geographical dispersion respectively.

In **MAP: AREA OF APPLICATION**, every relevant innovation case have been sorted by the untapped opportunity within blue bio-economy that they seek to utilize, and/or every issue they seek to remedy. While the specifics of each opportunity and issue branch out into innumerable nuances, the following thematic areas have been chosen to represent the different applications of sustainable blue innovation:





FOCUSED ON OPPORTUNITIES

01

Maritime Harvest
Every innovation that sustainably makes use of novel species, methods, and derivative products like bycatch and driftwood and -weeds in order to create new value in and from marine bio-economies.
***Keywords**: algae and seaweed farming; fishing & bycatch; driftwood; other marine resources*

02

Maritime Production
Every innovation that sustainably utilizes the ocean space itself as a platform for production, eco-tourism, research etc.
***Keywords**: renewable energy; mariculture; off-shore and floating infrastructure; eco-tourism; deep sea mining*

03

Regenerative
While innovations that directly accelerates the restoration of damaged or vulnerable marine environments are few and far between and in very early stages, less than 14% of our cases have an indirect impact on marine regeneration. Either through conservation and protection, improved monitoring, and/or expanding the reach of benevolent actors in the bio-economies.
***Keywords**: biodiversity; restoration of ecosystem; fishstock sustainability; water purification; recycling, upcycling; monitoring*

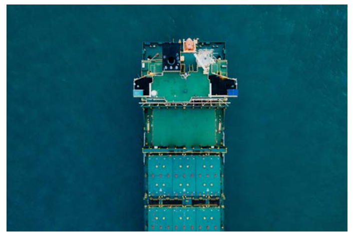
FOCUSED ON ISSUES

01

Waste Management
All innovations that minimize waste entering the oceans - be it plastic, chemical, industrial, urban, or from maritime industries.
***Keywords**: prevention and remediation of waste, debris and pollutants; ghost nets; excess nutrients; spills*

02

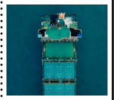
Climate Change
All innovations that seek to mitigate the effects of climate change on marine ecosystems or utilize oceanic resources to decelerate or negate global climate change.
***Keywords**: ocean mapping; monitoring of global parameters; diversity of species; rising sea levels; extreme weather; carbon drawdown*



03

Destructive Industries
All innovations that optimize, reform or transform current industries (based on or affecting the oceans) as part of a pragmatic transition to more sustainable practices.
***Keywords**: shipping; fishing; tourism; emissions; noise; mining and drilling; monitoring*

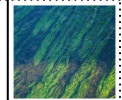
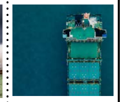
MAP: AREA OF APPLICATION

Company name	Link	Focused on opportunities			Focused on issues		
		Maritime Harvest	Maritime Production	Regenerative	Waste	Climate change	Destructive industries
							
Agilyx	🔗				1		
Alga plus	🔗	1					
AlgaePro AS	🔗	1					
Ankeri	🔗						1
Aptomar	🔗			2			2
Ashored	🔗	2					2
B'ZEOS	🔗	1					
Beex	🔗			1			
Berring Data Collective	🔗	2					2
Big Eye Smart Fishing	🔗	2					2
Bionic Yarn	🔗				2		2
BlockCycles	🔗				1		
Blue benu	🔗		3	3	3		
Blue Bio Value	🔗						1
Blue economy	🔗	2	2				
Blue INNOship	🔗						1
Blue Ocean Robotics	🔗				2		2
Blue Rise	🔗	3	3				3
Blue Technology	🔗						1
Bluemater	🔗				1		
Blueye Robotics	🔗					2	2
Boos	🔗						1
Bound4blue	🔗						1
Bureo	🔗				2		2
BW Monitor	🔗						1
Callenberg	🔗						1
CalWave	🔗	2	2				
Carnegie	🔗	2	2				
Coach Solutions	🔗						1
Cool4sea	🔗						1
Coral Vita	🔗			2		2	
Corpower Ocean	🔗	2	2				
Danelec	🔗						1

* See case description in corresponding section

Company present in...
■ (light grey) = 1 vertical ■ (dark grey) = 2 verticals ■ (blue) = 3 verticals

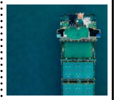
MAP: AREA OF APPLICATION

Company name	Link	Focused on opportunities			Focused on issues		
		Maritime Harvest	Maritime Production	Regenerative	Waste	Climate change	Destructive industries
							
Dansk Tang	🔗	1					
Demogate	🔗			2	2		
DESMI	🔗						1
DHI	🔗					2	2
Eco Marine Power	🔗						1
Eco Wave Power	🔗	2	2				
Ecotone	🔗		2				2
EGGS Design	🔗						1
Eneco	🔗	2					2
Eurogoos	🔗						1
Floating Powerplant		2	2				
Futuralga	🔗	2			2		
Green Sea Guard Limited	🔗						1
Green ship of the future	🔗						1
GreenOcean	🔗			2	2		
Hempel	🔗						1
HeraSpace	🔗	2					2
Hoekmine	🔗						1
Hydrotroniks	🔗						1
Ichthion	🔗			3	3		3
Innovesi	🔗			1			
Insa Tech							1
IOOS	🔗						1
Jets	🔗				1		
Jupiter Hydro	🔗						1
L3 ASV	🔗						1
Lemvig Biogas	🔗	2			2		
LOLIWARE	🔗	2			2		
Longline Environment	🔗	2					2
Lusalgae	🔗	1					
Mara Seaweed	🔗	1					
Maritime Robotics	🔗						1
Nobriner	🔗	3			3	3	

* See case description in corresponding section

Company present in...
■ (light grey) = 1 vertical ■ (dark grey) = 2 verticals ■ (blue) = 3 verticals

MAP: AREA OF APPLICATION

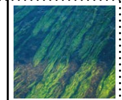
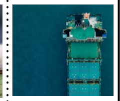
Company name	Link	Focused on opportunities			Focused on issues		
		Maritime Harvest	Maritime Production	Regenerative	Waste	Climate change	Destructive industries
							
Nova Grass	🔗			■ 2		■ 2	
Ocean Energy	🔗	■ 2	■ 2				
Ocean Finance	🔗						■ 1
Ocean Harvest Technology	🔗	■ 2					■ 2
Ocean Harvesting Technologies	🔗	■ 2	■ 2				
Ocean Sun	🔗	■ 2	■ 2				
Oceana	🔗					■ 2	■ 2
Olrac Marine Observer (OLSPS)	🔗						■ 1
One Earth One Ocean	🔗		■ 3	■ 3	■ 3		
OSV finder	🔗						■ 1
Penwave	🔗	■ 1					
Plan Blue	🔗					■ 1	
Plastic change	🔗				■ 1		
Plastic Whale	🔗			■ 2	■ 2		
RanMarine Technology	🔗			■ 1			
Remora Marine	🔗			■ 1			
Retrofitting	🔗				■ 2		■ 2
SafetyNet Technologies	🔗	■ 1					
Sea-grass	🔗	■ 1					
Sea2cradle	🔗				■ 1		
Seabin Project	🔗			■ 2	■ 2		
Seaentia	🔗	■ 1					
Seaweed & Co	🔗	■ 1					
Sedni	🔗						■ 1
Sertica	🔗						■ 1
Shipping Lab	🔗						■ 1
Smart Marine Systems	🔗				■ 1		
Sofaroceans	🔗					■ 2	■ 2
Solrød Biogas	🔗	■ 2			■ 2		
Southern Blue Reef	🔗	■ 2				■ 2	
Stingray	🔗	■ 1					
Sundrop farms	🔗	■ 2		■ 2			
Susteq	🔗	■ 2		■ 2			

Company present in...

* See case description in corresponding section

■ 1 = 1 vertical ■ 2 = 2 verticals ■ 3 = 3 verticals

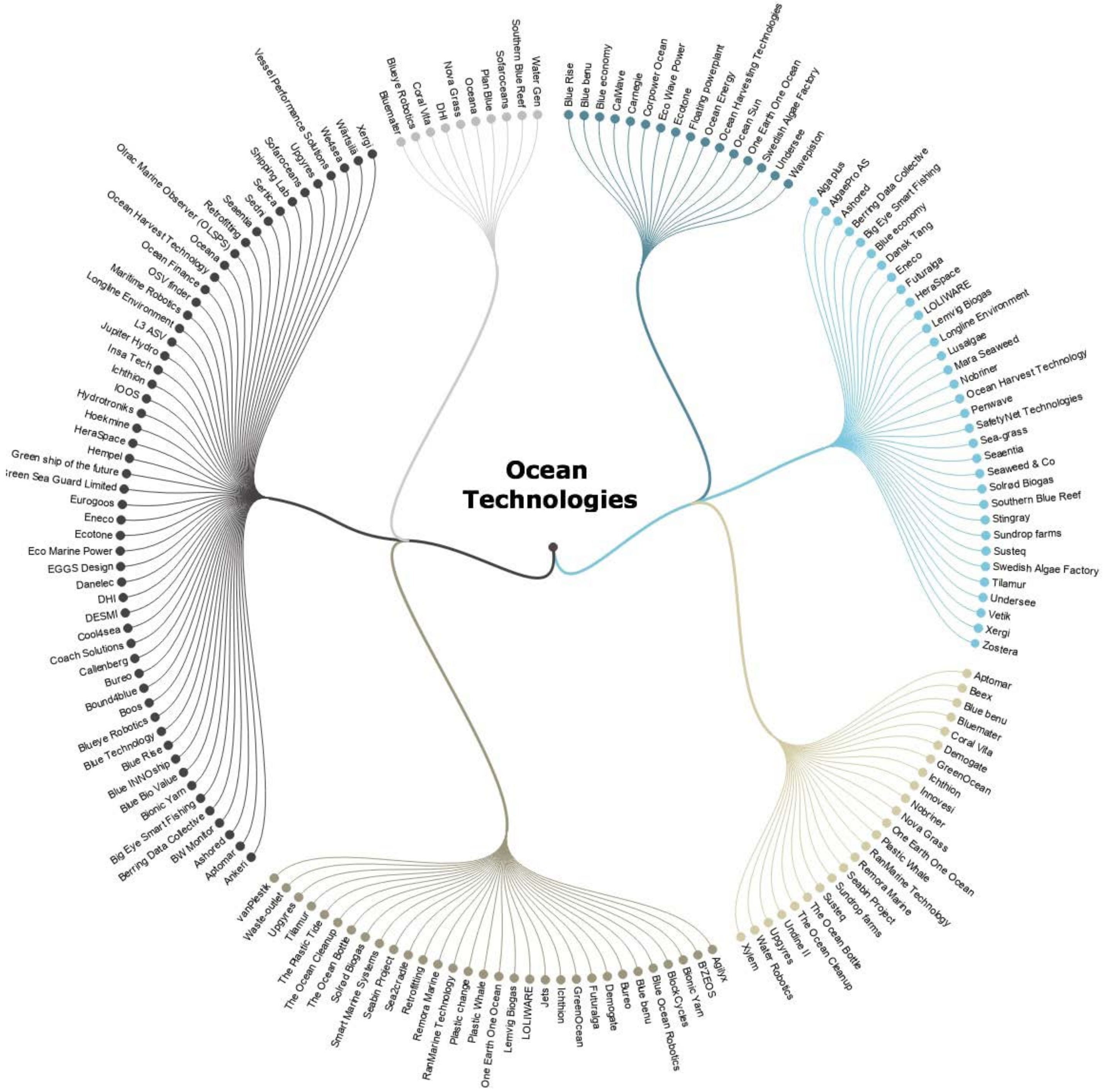
MAP: AREA OF APPLICATION

Company name	Link	Focused on opportunities			Focused on issues		
		Maritime Harvest	Maritime Production	Regenerative	Waste	Climate change	Destructive industries
							
Swedish Algae Factory	🔗	■ 2	■ 2				
The Ocean Cleanup	🔗				■ 1		
The Plastic Tide	🔗				■ 1		
TheOceanBottle	🔗			■ 2	■ 2		
Tilamur	🔗	■ 2			■ 2		
Undersee	🔗	■ 2	■ 2				
Undine II	🔗			■ 1			
Upgyres	🔗				■ 1		
vanPlestik	🔗				■ 1		
Vessel Performance Solutions	🔗						■ 1
Vetik		■ 1					
Wärtsilä	🔗						■ 1
Waste-outlet	🔗				■ 1		
Water Gen	🔗					■ 1	
Water Robotics	🔗			■ 1			
Wavepiston	🔗	■ 2	■ 2				
We4sea	🔗						■ 1
Xergi	🔗	■ 2					■ 2
Xylem	🔗			■ 1			
Zostera	🔗	■ 1					

Company present in...

* See case description in corresponding section

■ 1 = 1 vertical ■ 2 = 2 verticals ■ 3 = 3 verticals



Focused on issues:

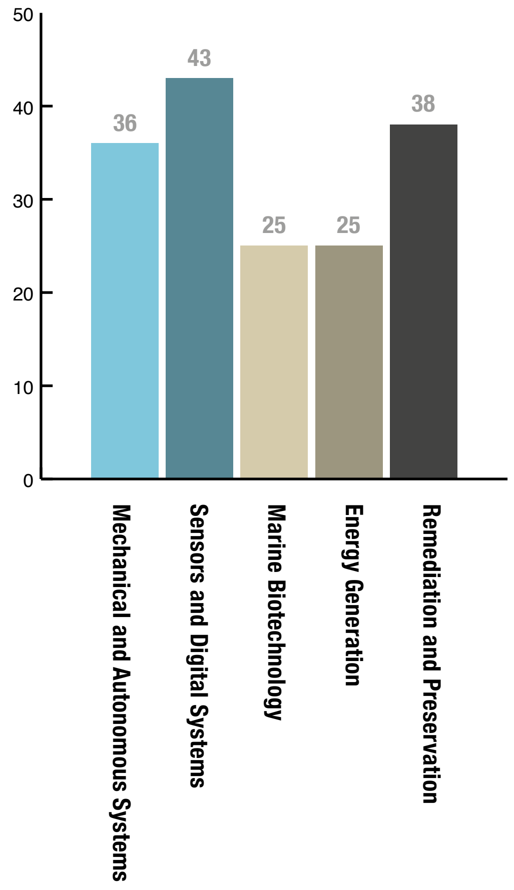
- Climate change
- Destructive Industries
- Waste

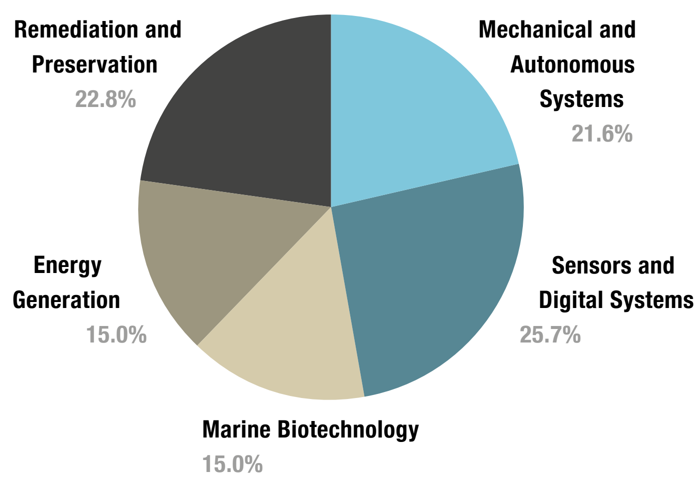
Focused on opportunities:

- Maritime Production
- Maritime Harvest
- Regenerative

Fig: Dendogram - Ocean technologies divided in areas

In **MAP: TECHNOLOGY TYPE**, the innovation cases have been sorted by the technology types they employ. Again the interdisciplinarity and flexibility of many startups becomes evident. Some startups branch across several technologies to achieve their goals. Others present innovation that are or can become highly synergistic with other technology types. To represent these patterns and facilitate a qualified prediction of the next steps of ocean technology innovation, the following five overarching technological categories have been distinguished:





TECHNOLOGY TYPES

Mechanical and Autonomous Systems

This category covers the implementation of robotics and drones, autonomous vessels and equipment. It also includes mechanical innovations that improve the sustainability of current maritime efforts and/or extends the reach of human exploration and intervention in marine ecosystems.

***Keywords**: robotics; drones; autonomous vehicles and equipment; hardware and mechanical innovations*

Sensors and Digital Systems

This category covers networks of sensors (Internet of Things), as well as digital innovations like platforms for monitoring and analysis (of ecosystems or maritime vessels), cloud-based maps and software that significantly improves the resource efficiency and sustainability of current actors.

***Keywords**: IoT; big data analytics; AI and machine learning; cloud technology; platforms*

Marine Biotechnology

This category includes innovations related to marine biological resources like algae and seaweed, utilized in a wide range of fields, from food production and medicine to construction and plastic alternatives.

***Keywords**: R&D in marine biology; plastic replacements; pharmaceuticals; nutrients; biogas*

Energy Generation

This category includes innovations related to marine bio-refineries, maritime energy production and integrated marine power sources.

***Keywords**: bio-refineries; maritime energy generation; integrated marine power sources*

Remediation and Preservation

This category covers purification methods, recycling and other regenerative innovations, that either minimize waste in the oceans or restore the maritime infrastructure damaged by climate change.

***Keywords**: purification; regeneration; recycling; upcycling; filters; ecosystem protection*

MAP: TECHNOLOGY TYPE

Company name	Link	Mechanical and Autonomous Systems 	Sensors and Digital Systems 	Marine Biotechnology 	Energy Generation 	Remediation and Preservation 
Agilyx	🔗					1
Alga plus	🔗			1		
AlgaePro AS	🔗			2	2	
Ankeri	🔗		1			
Aptomar	🔗		1			
Ashored	🔗	2	2			
B'ZEOS	🔗					1
Beex	🔗	1				
Berring Data Collective	🔗		1			
Big Eye Smart Fishing	🔗		1			
Bionic Yarn	🔗					1
BlockCycles	🔗					1
Blue benu	🔗			3	3	3
Blue Bio Value	🔗		1			
Blue economy	🔗		1			
Blue INNOship	🔗	2	2			
Blue Ocean Robotics	🔗	3	3			3
Blue Rise	🔗	2			2	
Blue Technology	🔗	1				
Bluemater	🔗			2		2
Blueye Robotics	🔗	1				
Boos	🔗		1			
Bound4blue	🔗	1				
Bureo	🔗					1
BW Monitor	🔗		1			
Callenberg	🔗	1				
CalWave	🔗				1	
Carnegie	🔗	2			2	
Coach Solutions	🔗		1			
Cool4sea	🔗	1				
Coral Vita	🔗			2		2
CorPower Ocean	🔗	2			2	
Danelec	🔗		1			

* See case description in corresponding section

Company present in...
■ = 1 vertical ■ = 2 verticals ■ = 3 verticals

MAP: TECHNOLOGY TYPE

Company name	Link	Mechanical and Autonomous Systems	Sensors and Digital Systems	Marine Biotechnology	Energy Generation	Remediation and Preservation
						
Dansk Tang	🔗			1		
Demogate	🔗		2			2
DESMI	🔗	1				
DHI	🔗		2	2		
Eco Marine Power	🔗	2			2	
Eco Wave Power	🔗				1	
Ecotone	🔗	2	2			
EGGS Design	🔗		1			
Eneco	🔗				1	
Eurogoos	🔗		1			
Floating Powerplant	🔗	2			2	
Futuralga	🔗			1		
Green Sea Guard Limited	🔗		1			
Green ship of the future	🔗		1			
GreenOcean	🔗					1
Hempel	🔗	1				
HeraSpace	🔗		1			
Hoekmine	🔗		2	2		
Hydrotroniks	🔗	2			2	
Ichthion	🔗	3			3	3
Innovesi	🔗		2			2
Insa Tech		2	2			
IOOS	🔗		1			
Jets	🔗	2				2
Jupiter Hydro	🔗	1				
L3 ASV	🔗	1				
Lemvig Biogas	🔗			2	2	
LOLIWARE	🔗					1
Longline Environment	🔗		1			
Lusalgae	🔗			1		
Mara Seaweed	🔗			1		
Maritime Robotics	🔗	1				
Nobriner	🔗					1

Company present in...

* See case description in corresponding section

■ = 1 vertical ■ = 2 verticals ■ = 3 verticals

MAP: TECHNOLOGY TYPE

Company name	Link	Mechanical and Autonomous Systems	Sensors and Digital Systems	Marine Biotechnology	Energy Generation	Remediation and Preservation
						
Nova Grass	🔗					1
Ocean Energy	🔗	2			2	
Ocean Finance	🔗	1				
Ocean Harvest Technology	🔗			1		
Ocean Harvesting Technologies	🔗				1	
Ocean Sun	🔗				1	
Oceana	🔗	1				
Olrac Marine Observer (OLSPS)			1			
One Earth One Ocean	🔗				2	2
OSV finder	🔗		1			
Penwave	🔗			1		
Plan Blue		2	2			
Plastic change	🔗					1
Plastic Whale	🔗					1
RanMarine Technology	🔗	2				2
Remora Marine	🔗		2			2
Retrofitting	🔗	2				2
SafetyNet Technologies	🔗		1			
Sea-grass	🔗			1		
Sea2cradle	🔗		2			2
Seabin Project	🔗					1
Seaentia	🔗			1		
Seaweed & Co	🔗			1		
Sedni	🔗		1			
Sertica	🔗		1			
Shipping Lab	🔗	1				
Smart Marine Systems	🔗	3	3			3
Sofaroceans	🔗		1			
Solrød Biogas	🔗			2	2	
Southern Blue Reef	🔗			2		2
Stingray	🔗	2	2			
Sundrop farms	🔗			2	2	
Susteq	🔗					1

Company present in...

* See case description in corresponding section

■ = 1 vertical ■ = 2 verticals ■ = 3 verticals

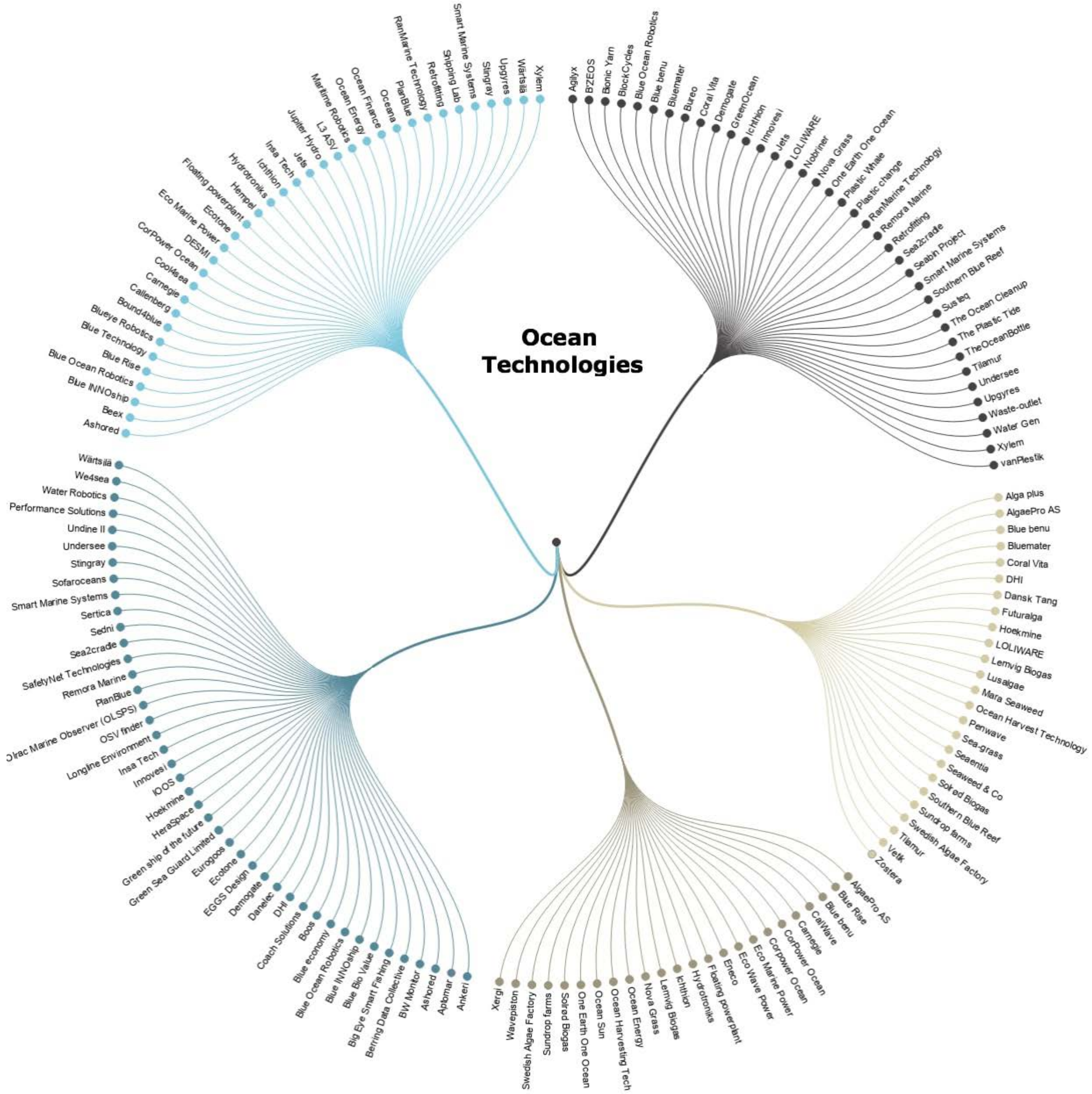
MAP: TECHNOLOGY TYPE

Company name	Link	Mechanical and Autonomous Systems	Sensors and Digital Systems	Marine Biotechnology	Energy Generation	Remediation and Preservation
						
Swedish Algae Factory	🔗			■	■	
The Ocean Cleanup	🔗					□
The Plastic Tide	🔗					□
TheOceanBottle	🔗					□
Tilamur	🔗			■		■
Undersee	🔗		■			■
Undine II	🔗		□			
Upgyres	🔗	■				■
vanPlestik	🔗					□
Vessel Performance Solutions	🔗		□			
Vetik				□		
Wärtsilä	🔗	■	■			
Waste-outlet	🔗					□
Water Gen	🔗					□
Water Robotics	🔗		□			
We4sea	🔗		□			
Xergi	🔗				■	
Xylem	🔗	■				■
Zostera	🔗			□		

* See case description in corresponding section

Company present in...

□ = 1 vertical   ■ = 2 verticals   = 3 verticals



Remediation and Preservation

Sensors and Digital Systems

Marine Biotechnology

Mechanical and Autonomous Systems

Energy Generation

Fig: Dendogram - Ocean technologies divided in technology types

MAP: GEOGRAPHICAL DISTRIBUTION

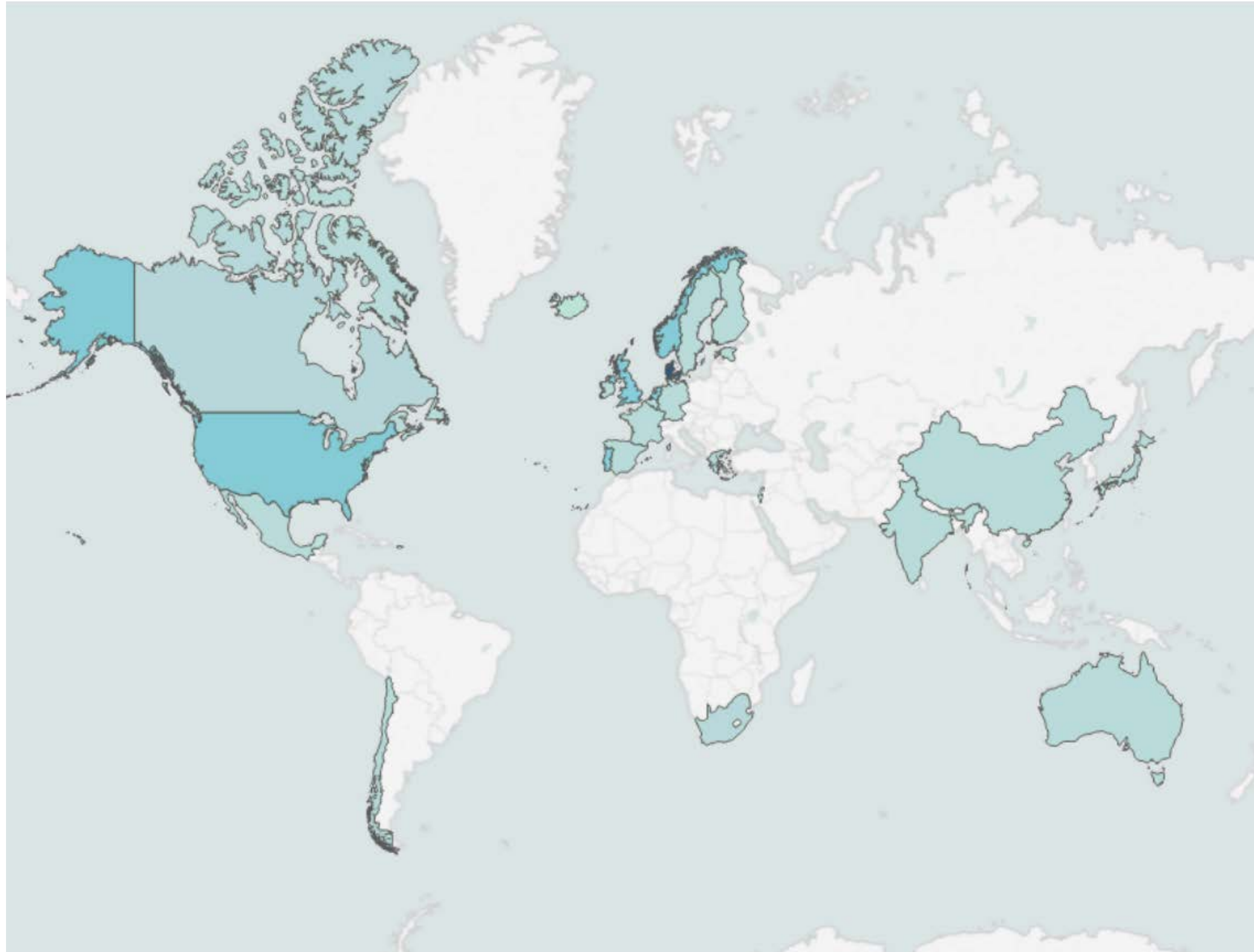


Fig: World map - Ocean technologies divided by geography

MAP: HIGHLIGHTED CASES

Company name & solution	Link	Focused on opportunities	Focused on issues
AlgaePro AS (NO) Producing sustainable algal biomass for multiple high-value and bulk markets		Maritime Harvest: Algae farming	-
Berring Data Collective (DK) Integrating automatized sensors into industrial fishing equipment		Maritime Harvest: Fishing	Destructive Industries: Overfishing
Big Eye Smart Fishing (PT) Providing digital technologies that can improve sustainable seafood harvesting		Maritime Harvest: Fishing; Marine resources	Destructive Industries: Overfishing
Bionic Yarn (US) Engineering fully traceable high-grade textiles and polymers made with coastal and marine plastic		Regenerative: Recycling	Waste: Plastic pollution
BlueBenu (DK) Producing eco-fuel for the maritime industry using plastic waste collected from the oceans		Maritime Production: Renewable energy	Waste: Plastic Pollution
Blueye Robotics (NO) Inspecting aquaculture plants, ships, infrastructure, and complex research operations using drone technology		-	Destructive Industries: Shipping, Tourism
Bound4blue (SP) Developing wingsail systems that reduce fuel consumption and pollutant emissions by up to 40%		-	Destructive Industries: Shipping
Demogate (GE) Integrating automatized sensors into industrial fishing equipment		Regenerative: Recycling	Waste: Debris
Eco Marine Power (JP) Developing sustainable shipping solutions, e.g the world's first ship powered by solar sails		-	Destructive Industries: Shipping
Ecotone (NO) Developing hyperspectral ocean vision for ocean mapping and fish farm monitoring		Maritime Production: Mariculture	Destructive Industries: Drilling
Floating Powerplant (DK) Integrating wave and wind power in offshore power plants		Maritime Production: Renewable energy	-
Green Sea Guard Limited (UK) Providing products and services that monitor fuel waste and particulate emissions		-	Destructive Industries: Shipping; Overfishing

MAP: HIGHLIGHTED CASES

Company name & solution	Link	Focused on opportunities	Focused on issues
Hera Space (UK) Using blockchain technology and satellite photos to guide fishermen towards sustainable fishing grounds		Maritime Harvest: Fishing	Destructive Industries: Overfishing
Ichthion (UK) Integrating pollution extraction into established echnologies and infrastructures		Regenerative: Upcycling	Waste: Plastic pollution
Loliware (US) Producing single use products from seaweed to replace plastics		Maritime Harvest: Seaweed farming	Waste: Plastic pollution
NoBriner (DK) Providing a desolation method, that reject brine in an ecologically harmless way		Regenerative: Water purification	-
NOVAGRASS (DK) Providing habitats and nursery grounds for restoring biodiversity and harvesting seagrass seeds		Regenerative: Biodiversity; Restoration	Climate Change: Carbon drawdown
Ocean Harvest Technology (IR) Producing sustainable animal feed from seaweed, simultaneously improving the nutritional profile		Maritime Harvest: Seaweed farming	Destructive Industries: Emissions
Ocean Sun (NO) Building large-scale floating solar power plants in coastal seawater, lakes, and reservoirs		Maritime Production: Renewable energy	-
Oceana (SWE) Developing autonomous vessels for environmental measurements, surveys, and oceanology investigations		-	Destructive Industries: Shipping
OSV Finder (FR) Improving performance with less ships by coordinating ship fare - the Uber of shipping		-	Destructive Industry: Shipping
PlanBlue (US) Mapping and investigating the oceans using intelligent underwater cameras		-	Climate Change: Monitoring
Retrofitting (DK) Remodelling old ships helping them comply with new environmental legislations		Waste: Recycling	Destructive Industries: Shipping
Sofarocean (US) Developing ocean sensors and drones that describe and predict the marine environment		-	Climate Change: Monitoring

MAP: HIGHLIGHTED CASES

Company name & solution	Link	Focused on opportunities	Focused on issues
Solrød Biogas (DK) Producing biogas from seaweed and waste materials		Maritime Harvest: Seaweed farming	Waste: Excess nutrients
Sundrop Farms (AU) Producing sustainable agriculture by using ocean water and solar power		Maritime Harvest: Marine resources	Climate Change: Extreme weather
Susteq (NL) Developing water purification solutions, e.g. making ocean water drinkable		Maritime Harvest: Marine resources	-
Swedish Algae Factory (SE) Cultivating certain algae for water purification, energy production, decarbonisation, and biomass production		Maritime Harvest: Algae farming	-
The Ocean Bottle (UK) Funding the collection of 11 kgs ocean bound plastic by selling sustainable drinking bottles		Regenerative: Upcycling	Waste: Plastic pollution
Undersee (PT) Monitoring and collecting aquaculture data securing water quality and water security		Maritime Production: Mariculture; Infrastructure	-
Undine II (DK/GER) Creating awareness of the maritime bio-economy through education, eco-tourism and interdisciplinary cooperation		Regenerative: Restoration (efforts)	-
VanPlestik (NL) Repurposing end-of-life plastic waste into high quality 3D-printing filament		-	Waste: Plastic pollution
Waste-Outlet (DK) Trading waste from their international platform - all waste is treated as a resource		-	Waste: Plastic pollution
WavePiston (DK) Producing sustainable energy from a new type of cheap wave technology		Maritime Production: Renewable energy	-
We4sea (NL) Providing non-CAPEX monitoring solutions for ships, improving fuel efficiency and emission reduction.		-	Destructive Industries: Shipping
Zostera (DK) Developing sustainable building materials using eelgrass as raw material		Maritime Harvest: Seaweed farming	-

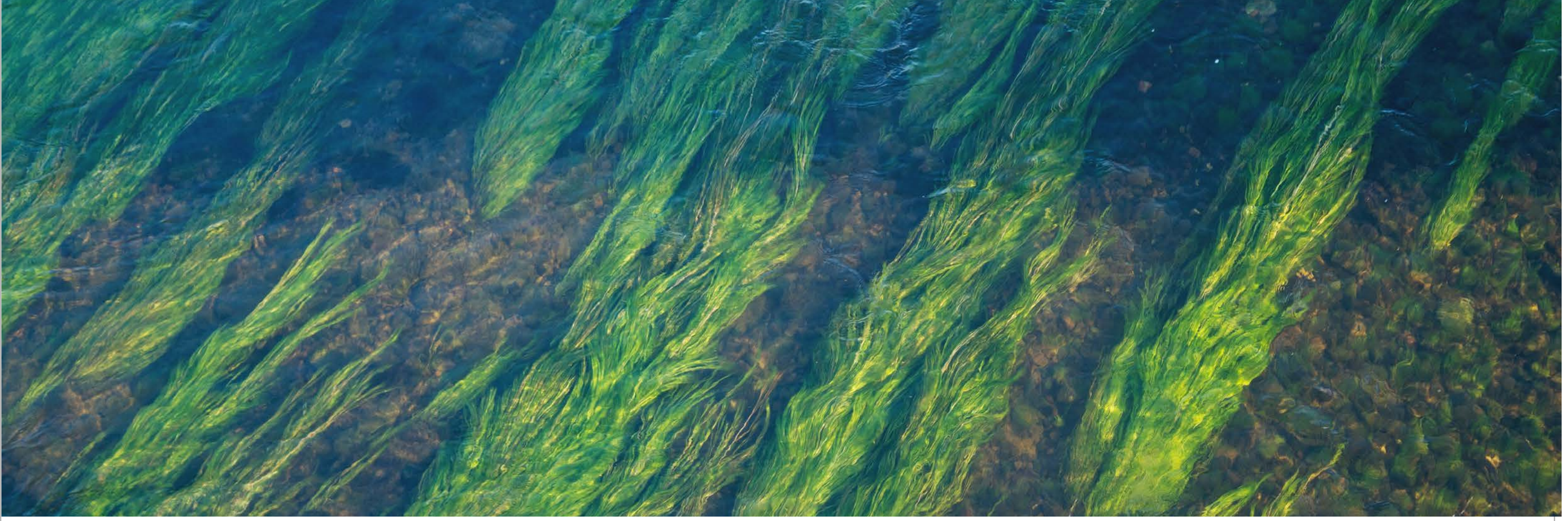
05

BLUE TECHNOLOGY TRENDS

BLUE TECHNOLOGY TRENDS

In mapping the current landscape of innovators within ocean technologies, the aim has been to illustrate the breadth of issues tackled by these innovators and the multifaceted approach of many startups: by developing and combining technologies in novel ways, they aim to solve pertinent sustainability issues and at the same time explore the untapped resources of marine bio-economies. This is why 38% of the 121 innovation cases analyzed in this report appear as intersections in **MAP: AREA OF APPLICATION**, and 34,7% display interdisciplinarity as seen in **MAP: TECHNOLOGY TYPE**.

The following section presents an analysis of the trends within each category from **MAP: AREA OF APPLICATION**, making predictions for potential applications and future synergies of relevant technology types within that thematic area.



MARITIME HARVEST

This area shows a staggering potential as well as a few pitfalls. Marine-based biotechnology is still in very early stages with most of the research being undertaken by university departments. The biotechnology innovation cases identified in this horizon scan all utilize single algae species for multiple purposes. Further research will lead to highly specialized and highly efficient applications in multiple sectors. The fact that one startup (Case #3: Swedish Algae Factory) can derive highly nutritious foodstuffs, a nanocoating for solar panels, as well as enzymes with medical potential - all from one connected production process - signals a wide scope of potentials. Several innovations in the use of seaweeds have also been identified with application potential in construction, furniture, and biogas.

PREDICTIVE SCENARIOS WITH CASE EXAMPLES

Within 5 years, we should see easily distributable nutritional supplements for disaster- and war-zones, six new types of antibiotics, combating the rise of multi-resistant bacteria, as well as more efficient solar panels. We should also see the normalization of marine flora in culinary industries, as well as several CO_2 neutral products for home construction and decor.

See for example: Seagrass Tech for nutritional supplements from seaweed, Case #3: Swedish Algae Factory for more efficient solar panels using algae, among other things, Seaweed & Co for food products from seaweed, and Zostera for insulation materials from seaweed.

In 20 years the photosynthesis of marine flora may provide the key to carbon-based self-healing materials for ships and offshore infrastructure.[26] By that time most coastal communities will also have easy access to seaweed-based filaments for 3D printers, making more sustainable construction globally scalable.

See for example: Algaepro AS, Penwave, and Case #3: Swedish Algae Factory for more innovations within the use of algae.

MARITIME PRODUCTION

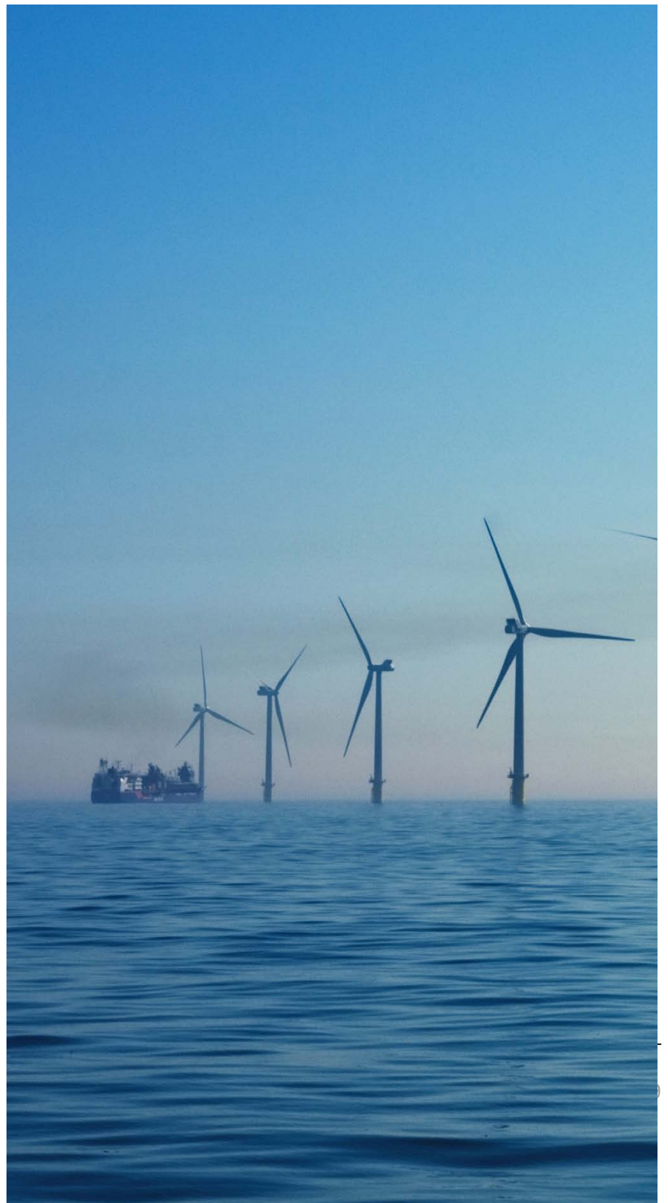
In this area we see a couple of dark horses - innovations that could be big, but are currently very overlooked. Additionally, quite a few efforts to transfer and implement industries from land to sea exist. Most important of these efforts are the variety of innovations in solar and/or hydro energy that are either efforts to install solar panels on floating infrastructure or adapting dam turbines to capture energy from waves. Both innovations have proven effective at generating electricity, but long term maintenance in a saline environment is still posing a challenge.

New innovations using AI, IoT, autonomous monitoring, and big data analytics address issues in the field of aquaculture, such as invasive species, water pollution, fish waste smothering plants and animals on the seafloor, as well as the spread of diseases and parasites to wild fish, which are common occurrences in crowded pens.[27] Aquaculture may be the only way to supply a growing demand for seafood as the human population grow, and research suggest that wide scale aquaculture utilizing much of the ocean's coastal waters, could outproduce the global demand for seafood by a staggering 100 times.[28] Also, aquaculture has the potential of restoring wild fish stocks,[29] and halting the depletion of global fish stocks endangered by years of overfishing, pollution, acidification, and disappearing corals reefs.[30] Whether the aquacultural potential outweighs the consequences, is still dependent on further development in monitoring the internal and external marine environment of aquafarms, and efficient extraction of fish waste and chemicals, that could be utilized for biogas production.

To make this happen, legislation is an important first step as this is one area, where laws have hindered technological implementation and improvement of current practises, simply because the legislation hasn't followed suit with the technological development (**Case #3: Swedish Algae Factory**) is again a good example but there are others, e.g. one university spinoff from DTU doing optic sensors that was unable to enter the market of Norwegian mariculture because of this).

Of the overlooked potential, the first is eco-tourism. While 87% of travelers want to travel sustainably,[31] we did not see any innovations in this field. Some innovations on business models do exist, like **The Waste Kayak** in Copenhagen where users rent the kayak for free, but commit to collecting trash from the canals and post photos on social media. There is a growing demand for eco-tourism, and developing technologies that help integrate sustainable tourism practises into coastal and marine environments should provide considerable benefits; not only for marine environments in the form of added protection and financial premiums dedicated to restoration and conservation, but also at a public awareness level.

The second overlooked opportunity is deep sea mining. While marine ecosystems would undoubtedly be better off with zero exploitation of seabed riches, it is unthinkable that the valuable minerals will be left untouched. This could be a chance for innovators to develop methods of maritime harvest that have a minimal environmental impact.



PREDICTIVE SCENARIOS WITH CASE EXAMPLES

Within 5 years we should see more offshore power plants, exploiting the vast areas occupied by the oceans - approximately 71% of earth's surface is covered by water. Besides the major opportunity of upscaling sustainable energy production, offshore technology hold the potential of freeing valuable areas occupied by land-based power plants. In addition, the offshore platforms can reduce evaporation, which is a growing concern in countries already affected by warmer climates as a result of climate change.[32] If legislation follow suit, we should also see an expansion of monitoring solutions combined with intelligent data collection making mariculture farms and aquaculture in general more sustainable and cost-effective - and thus the scaling of such more attractive.

We could also see eco-tourism resorts and retreats that have been tailored to the local settings, where travelers and volunteers take active part in the restoration of marine environments. To this end, user friendly subsurface drones will help extend the reach and experience of human actors without harming coastal ecosystems. We could also see advanced versions of these drones used for exploitation of seabed minerals, with potentially detrimental consequences to marine bio-economies.

See for example: **Ocean Sun** for floating solar platforms, **Floating Powerplant** for combined wind and wave power platforms, **Longline Environment** for environmental consulting on sustainable aquaculture, **Stingray** for intelligent aquaculture technology increasing food production on nature's terms, **Lemvig Biogas** for biogas production from fish waste, and **Undine II** for eco-tourism and restoration of the marine environment.

In 20 years the combination of drones with advanced AI analytics and sophisticated robotics could provide a more sustainable way of accessing the seabed resources. The same technology should see us achieving scientific breakthroughs on deep ocean ecosystems, a largely unexplored part of our planet.

See for example: **Beex** for autonomous underwater robots, **Ecotone** for ocean floor mapping using hyperspectral images, and **Aptomar** for environmental monitoring for drilling campaigns.

REGENERATIVE

In the mapping, various innovations that indirectly support the restoration of blue bio-economies have been included, for example various of the sensor and mapping technologies that provide crucial information on the health and status of ocean environments. This data informs scientific groundwork and non-commercial actors that seek to protect vulnerable bio-economies. Simultaneously it provides a precise image of maritime vessels and their effects on the oceans, a prerequisite for decisive and progressive legislation for the conservation of marine ecosystems.

When looking at explicitly regenerative technologies that directly accelerate the restoration of marine bio-economies, one thing is clear: it is very hard to do. With a few exceptions, the fastest way to restore a marine environment seems to be protecting it from human interference and then letting nature run its cause. Of all the cases examined for the mapping, a couple of innovations within transplantation of corals and seaweed exist, but they are very early stage and very labor intensive.

The challenge regarding regenerative technologies is related to a point already put forth in the introduction - the interconnectedness of the oceans. Regeneration in one marine environment, like transplanted corals or species of fish, is still susceptible to effects from mismanagement in other places along with the side-effects of global warming and other detrimental factors. Most efforts in this field are currently based in academia, with commercialization and development progressing at a very slow pace. One reason for this might be the relative invisibility of regenerative efforts, when compared to removing brightly colored chunks of plastic pollution from the oceans. Seeing improvement in a single ecosystem could take 20 to 50 years, even with accelerated regeneration.

PREDICTIVE SCENARIOS WITH CASE EXAMPLES

Within 5 years we should see examples of the cascading beneficial effects of e.g. transplanting eelgrass into Danish ecosystems. While the restoration itself will still be manual (and thus unscalable), adding networks of decentralized sensors (IoT) and AI analytics will greatly increase the precision of impact assessments. As real-time cloud-based maps of the ecosystems become available through other industries, awareness should increase among decision-makers, enabling more dedicated support for regenerative efforts.

See for example: **Case #7: NOVAGRASS** for large-scale eelgrass restoration, **Coral Vita** for transplanted coral into degraded sites, and **Sofarocean** for monitoring the marine environment.

In 20 years subsurface drones could be capable of re- and transplanting marine flora. This would greatly reduce the cost of regenerative efforts and provide a scalable solution to damaged coastal regions. The combination of extensive datacollection and automatized intervention shows the greatest potential, although it will require large amounts of soft funding and governmental support, as regeneration is hard to monetize within current paradigms. However, it is not unthinkable that actors in the tourism industry could join forces and invest in restoration in order to attract diving and fishing tourism. The area could also see breakthroughs in biotechnology, although genetically modified resilient plants or plastic-consuming algae will be impossible to contain if they are implemented. In a Danish context, the successful spread of seagrass meadows could lead to stronger industries based on this material. We have already seen the first early stage innovations in this field with seagrass being used for construction, furniture, and possibly even as filament for 3D printers.

See for example: **Case #1: Berring Data Collective** for the collection of oceanographic data, **Oceana** for autonomous monitoring of the maritime environment, and **Maritime Robotics** for unmanned vessels for maritime operations.

WASTE

In the last two years, concepts like "microplastics" and "Great Pacific Garbage Patch" have entered public awareness, ultimately through viral campaigns on social media. Plastic pollution in marine environments have become the visualization of a global problem. Visceral images of marine animals choking on plastics provide a tangible wake-up call to a deep-seeded problem in our society. The media exposure and public (self-) scrutiny has led to a surge in innovations in the area.[33] Startups concerned with removing plastic from marine environments make up the single largest group of cases in this analysis, indicating a direct connection between public awareness and the movements in innovation.

While plastic pollution remains a serious problem - in 2050 the weight of ocean plastics could surpass oceanic biomass - we have not identified any innovations that scale beyond manual or mechanic removal. It seems that the most efficient way of reducing plastic pollution is still to stop it from entering the oceans in the first place. An astonishing 90% of the plastic in the oceans originate from just 10 rivers,[34] making these an obvious target for efforts in this area. Looking at marine waste management more generally, the biggest potential seems to be in the area of IoT sensortechnology. Considerable steps have been taken by national and international legislative bodies to reduce marine waste and maritime emissions, but there is currently no way of ensuring adequate implementation of political initiatives. Inexpensive (or even profit-generating) sensors that can be retrofitted onto existing ships, gear and infrastructure opt as the best solutions on the current horizon.

Another trend in waste management is related to the increased public awareness. Community-based efforts are central to the efficiency and longevity of sustainability campaigns and efforts in waste management and removal. People care deeply about their local areas, and they want to be seen and heard acting on that drive. These community aspects could be combined with digitalized incentives (gamification and/or societal credits) to great effect. Digitality is vital to scaling this effort by monitoring efforts, connecting, and comparing to other communities, however, ultra-locality is vital to activating people in the first place and building ownership.

PREDICTIVE SCENARIOS WITH CASE EXAMPLES

Within 5 years we should see retrofitted efficient monitors that make it possible to level industry practices with legislative standards. Currently only 1 in 700 ships are monitored according to EU guidelines.[35] Similar monitoring should be feasible in most industries, drastically reducing waste and emissions affecting marine ecosystems. An IoT network should provide real-time data on not only pollution, but also single pieces of fishing gear, drastically reducing the tragic issue of drifting ghost nets. Simple social media-based platforms for tracking community-based activism on plastic cleaning should help reduce visibility of the problem in coastal regions, although the wider issue of increasing plastic and deep ocean pollution use is yet to be addressed. The first proof-of-concepts should hit the market showing considerable potential in upcycling physical pollution and debris, usable in consumer products at first, industry products, or in 3D printing as filament like The New Raw.

See for example: **TheOceanBottle** for consumer products, **Case #6: NoBriner** for industry products, **Retrofitting** for the integration of new technologies in old ships, **We4sea** and **Green Sea Guard** for emission and fuel monitoring, and **Waste-outlet** for waste trading.

In 20 years the newest developments in automated marine vehicles could merge with community activism, allowing for decentralized and scalable deployment of robotics with the simultaneous purpose of monitoring and cleaning marine environments. The integration of Product-as-a-Service business models allows this synergy to bypass potentially rigid national systems. Advanced monitoring and reporting sensors should be industry standards. The increased collection of pollution should be an integrated part of decentralized upcycling methods, like 3D printing and open-source tool-making. At this point, most of the world's population will have real-time personalized health data monitoring through their smartphones. It would be ideal to expand this capability with a personalized estimate on e.g. aggregated CO_2 emissions and waste generated, enabling synchronized efforts at mitigating ecological footprints.

See for example: **Ichthion** for pollution extraction integrated into established technologies and infrastructures, and **Case #5: BlueBenu** for eco-fuel production from oceanic plastic.

CLIMATE CHANGE

The issues related to climate change in a marine setting are numerous, as previously explained. Unlike the more visible and relatable consequences for humans on land, the ways in which blue bio-economies will deteriorate and suffer, are hard to grasp. Nonetheless, the effects of climate change on the oceans will be equally devastating for human societies, and they might be largely irreversible. Even modest increases in ocean temperature will disrupt marine habitats in ways we cannot account for yet. An overall increase in acidity will proportionately destabilize plankton and krill, the basis of oceanic food-chains.

As evident in **MAP: AREA OF APPLICATION**, we did not identify many innovators with the explicit goal of negating or reversing effects of climate change in marine settings or based on marine resources. It is possible that the efforts to halt global climate change will continue to be a land-based issue. In our best estimation, this would be a wasted opportunity in the best case scenarios, and a gross oversight of negative consequences in the worst scenarios.

Along with the awareness of growing deserts and more extreme weather, it should absolutely be common knowledge that not only will marine life suffer greatly (in terms of mass-extinctions and a decimation of marine biomass), but fundamental food security will be jeopardized. 4.3 billion people rely on marine protein for their regular diet.[36] Cutting that supply by 20% would be catastrophic.

PREDICTIVE SCENARIOS WITH CASE EXAMPLES

Within 5 years we should see the first innovations utilizing blue bio-economies to directly combat climate change. For example, plantations of seaweed and other marine flora have a huge potential in carbon drawdown. Controlled dispersal of ecologically safe brine from desalination plants might be able to offset the local desalination from melting glaciers and icecaps. We should also see data-backed models of the effects of climate change on the oceans. Combined with the proliferation of subsurface drones and cheap underwater cameras, the conditions of marine ecosystems should be as evident to the public as other climate events.

See for example: **Case #7: NOVAGRASS** for large-scale eelgrass restoration, **Case #3: Swedish Algae Factory** for decarbonisation using algae, **Sofaroceans** and **Case #2: Blueye Robotics** for environmental monitoring and underwater video footage.

In 20 years the precision and efficiency of aquaculture facilities could see a moderate shift from land-based agriculture to aquafarms, leading to decreased CO_2 emissions and decreased deforestation. It would be ideal for Danish innovators to build on the current world-class expertise in offshore renewable energy, and pursue a holistic integration with marine ecosystems, enabling offshore infrastructure to actively support ecosystems and provide an organic carbon drawdown.

See for example: **Coral Vita** for transplanted coral into degraded sites, **Southern Blue Reef** for constructed habitats for the marine ecosystem, and **Floating Powerplant** for combined wind and wave power platforms.

DESTRUCTIVE INDUSTRIES

As shown in the maps above, the startup ecosystem is heavily populated with innovations that improve the efficiency and sustainability of currently destructive industries, e.g. fishing, shipping, energy production, and tourism. Since every industry is interested in innovations that can improve competitive edge, startups are incentivized to develop solutions that can be easily integrated to the market space. This drives a constant momentum of incremental changes. It is beyond the scope of this report to account for all these short-term developments. Rather we focus on the possible innovations on a 5 to 20 year horizon respectively. For the sake of simplicity, the noteworthy trends within this area are described along three key avenues:

IoT Sensor Technology and AI. As discussed elsewhere, the proliferation of sensors will facilitate the creation of real-time maps on several parameters, from activity of single schools of fish, over water quality, to ecosystem health and geological conditions. When combined with cloud computing and AI analytics, the long-term costs of monitoring and analyzing data will drastically decrease. This flow of information will extend human knowledge below the surface to a new degree. By providing previously unseen levels of precise data it will level the playing field for fishermen, industrial players, and public entities including climate scientists. The increased data quality will also have a significant impact on a smaller scale for e.g. aquacultural facilities and for eco-tourist marine wildlife sanctuaries.

Blockchain. The technology has many staunch advocates and some very promising applications, but the integration into marine bio-economies might be less direct than expected. Blockchain technology is well suited for organizing large amounts of data among many digital actors. This obviously excludes the marine life itself, but it is ideal for organizing marine resources once they are harvested or produced. Specifically, blockchain allows for the precise tagging of time and place for a single fish.[37] The tag is converted to QR-codes that follow and add details in every step along the value chain until the consumer or restaurant receives and scans the final product. It is a decentralized system of accountability that will radically change our notion of and criteria for sustainably sourced resources.

It is still uncertain whether the transparent supply chain will provide sufficient value for industrial players to drive the innovation forward. If not, it will start out as an aspect of high-end commodities, until legislative bodies push legal requirements in the direction of ethical accountability.

Drone Technology and Automatization. Judging by current innovations and trajectories it seems inevitable that automatization will have a significant impact on established industries. As in many other cases the first innovations follow the biggest investments, meaning that the shipping industry will likely pioneer the field and introduce large-scale unmanned ships and increasingly digital monitoring of the entire value chain.[38] In their first iterations, the innovations will have little positive impact on marine bio-economies, save for the marginal decrease in emissions and fossil fuel burning. However, once developed the innovations are sure to trickle down to smaller scale, providing avenues of automatization for sectors directly engaged with sustainable ecosystems, who are currently limited by the high cost of human resources.[39] As the later cases should illustrate, the smaller underwater drones will provide easier access to inspection of ecosystems and maritime infrastructure, somewhat decreasing the negative impact of human interventions. However, it is probably with the integration of drone technology and innovation in sensors and AI mapping that we will begin to see significant benefits for marine ecosystems.

PREDICTIVE SCENARIOS WITH CASE EXAMPLES

Within 5 years we should see working concepts of real-time maps with single parameters, either showing water quality, fish stocks, or maritime activities. These maps alone will improve data-based efforts to combat overfishing and climate change, but large-scale benefits will still be absent due to the lack of scalable interfacing with marine environments. We should also see the first products from marine sources establishing a market niche by utilizing blockchain as a means for increased transparency and ethical accountability. Public reception will determine the speed of acceleration for blockchain innovations in traceability.

In the same time frame, the first largely automatized shipping vessels, possibly powered partially by innovations in solar-, hydro-, and wind energy are likely to appear. We will also see a modest proliferation of underwater and surface drones carrying cameras and monitoring ecosystem health. Integrating this data into the digital platforms mentioned above might take longer.

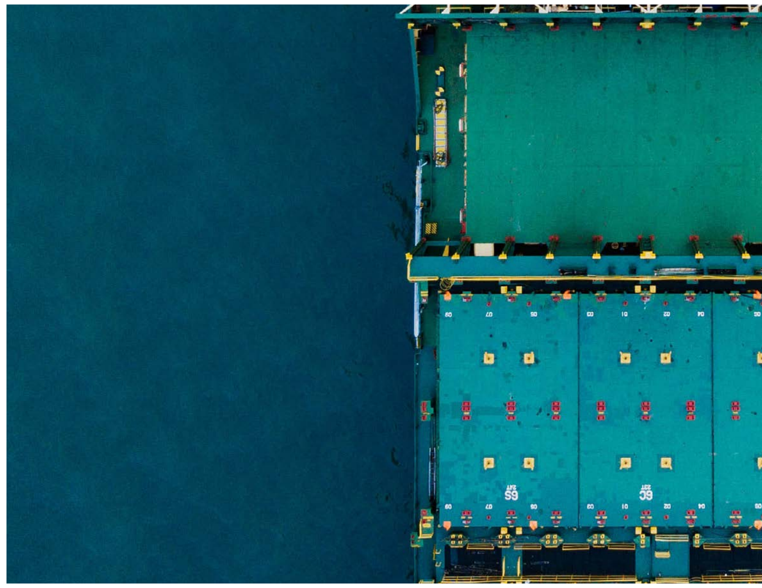
See for example: Big Eye Smart Fishing for digital technologies improving seafood sustainability, Hydrotroniks for electric fishing vessels, Bound4blue for wingsail systems that reduce fuel consumption and pollutant emissions, and OSV finder for digital coordination of shipping.

In 20 years we could see wikipedia-style real-time maps of marine ecosystems and maritime activities, aided by satellite data as well as autonomous drone fleets. New levels of transparency will inevitably lead to new levels of accountability, decreasing unmonitored overfishing and waste discharge. To see significant benefits for marine bio-economies, however, the new levels of data will require a simultaneous shift in regulative ambition, as well as private innovators dedicated to combining transparency and marketable scalable interventions.

See for example: Hera Space for blockchain technology and satellite photos that guide fishermen towards sustainable fishing grounds, L3 ASV for unmanned and autonomous marine systems, and Blue Ocean Robotics for maritime robotics.

Only if all three areas of data, innovation, and regulation show momentum, will we see the sufficient development of robotics necessary to scale interventions below the surface. Note that this future milestone in innovation will also be a bottleneck in the successful implementation of other areas, like biotechnology and regenerative solutions.

We could also see an integration of blockchain in most marine products with potentially harmful sourcing. At that point, blockchain integration could be an aspect of the production facilities, rather than separate tools and systems connected to the products themselves. Ultimately, the increased knowledge and transparency gained through IoT sensors and blockchain technology should provide the sufficient impetus to power a transformation of land-based industries in the direction of circular economic principles - the only way to fully halt and prevent the devastating effects of current production methods on marine bio-economies.

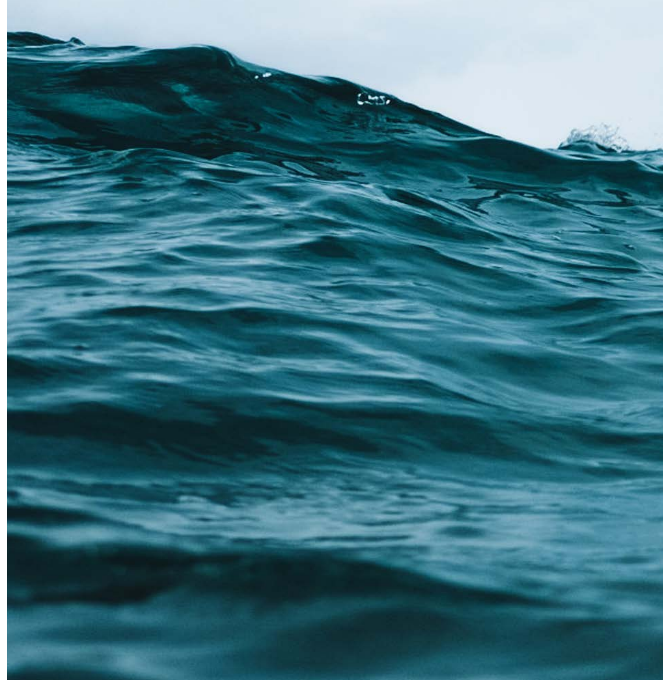


06

ENVIRONMENTAL IMPACT SCENARIOS FOR DENMARK

ENVIRONMENTAL IMPACT SCENARIOS FOR DENMARK

This section presents a preliminary assessment of the potential environmental impact for each technology type from **MAP: TECHNOLOGY TYPE**. Following the lines of the previous section, the assessment will take the form of a predictive scenario intended to showcase the strengths of each technology type, as it pertains to the Danish marine bio-economy. When looking at the strength of a technology type, two factors have been taken into account when constructing these qualitative scenarios: 1) its potential for affecting a meaningful regenerative impact on marine environments, and 2) the scalability and economic feasibility of the technology type.



MECHANICAL AND AUTONOMOUS SYSTEMS

It is within this technology type that we see the biggest overlap between current innovations and a potential for scaling impact. If the trends described in the last sections should come to their most fruitful implementation, we envision fleets of autonomous drones, constantly monitoring and measuring all aspects of marine ecosystem health. Given sufficient robotics development, they additionally would be grooming wild plants and underwater plantations, providing healthier ecosystems and more efficient production of marine resources. The plantations would act as efficient carbon drawdown systems, remove excess agricultural nutrients from Danish oceans, as well as provide habitat for increased biodiversity in coastal regions.

In total, this would form the technological basis for a new bio-economy based on healthy plant-based marine ecosystems, affecting a growth spiral of seaweeds and algae, repopulating the many Danish waters that lost natural seaweed habitats to fungal outbreaks in the 1930's (a boom akin to the regrowth of European forests due to increased plantational activity).

The automated drone fleets would simultaneously provide a stream of data to real-time 3D maps of water conditions, fish stocks as well as any human activity in those regions. Combined with satellite photography, this implementation would lead to a drastic decrease in unmonitored overfishing, and provide new magnitudes of data to inform national and international decision making on ocean protection and climate action.

SENSORS AND DIGITAL SYSTEMS

The increased functionality, precision, and connectivity of sensors in the oceans will be sufficient to drive the price/quality-ratio of sensor technology as well as a proliferation to virtually all pieces of blue equipment vessels and infrastructure. The diver camera manufacturer Paralenz is already working on installing sensors in their cameras, the data from those sensors could be merged with hundreds of other sensors to create a coherent and live-fed image of the conditions in the oceans. Within 20 years, retrofitting should be unproblematic, opening a whole new realm of opportunities. One could, for example, imagine the complete elimination of ghost fishing,[40] as retrofitted sensors combined with fizzy monitoring from various off-topic sensors, could warn autonomous garbage collection drones. As mentioned in the previous category, it is highly likely that industrial sectors will drive the price of drones and autonomous underwater vehicles down and

efficiency up. The mapping of fish ecology could be enough to drive the prices down, but much of the development will depend on the monetization of the collected data.

The limiting factor here is interfacing. No matter how detailed we map and analyse the oceans, the key factor in scaling interventions on issues (70% of plastic pollution sink)[41] or tapping into opportunities, will be the efficient implementation of robotics. In order to carry not only sensors and cameras, but arms to manipulate and containers for chemicals to be dispersed or trash to be cleaned.

If the general socio-economic trend continues with gamification of activism and Universal Basic Income, it seems probable that volunteer platforms can gain more pace - however, we do not deem it to be realistic that a non-commercialized platform vil gain momentum to be the game changer in this sector.

The sensors and digital systems could play a big part in future regulations on aquafarming, be it fish farms or algae farms, as pollution monitoring and influence on the near environments can be inspected at a much lower cost and higher precision.

MARINE BIOTECHNOLOGY

Marine biotechnology is the area investigated here with the longest R&D times and costs before investors have marketable products. This, in turn, implies long time before industrial scale investments and thus, industrial scale impact. However, enabling technologies such as AI-based lab-simulations, such as Labster's, and remote robotic IoT labs like the ones made by Inniti, can accelerate the R&D processes while cutting the associated costs and thus increase the demand for ocean-grown compounds.

Based on the economic impact and potential seen from enzymes (Novozymes) and natural bio-compounds (Chr. Hansen), the lab-based ocean grown products such as algae, are almost guaranteed to result in significant breakthroughs in synergy with existing industries (food, medicine, unknown chemical applications), and they will probably scale easily - once synthesized and proven in the market, mass-production is an inevitable next step. While the list of benefits to human land-based areas of innovation might be long, it is still not clear if the lab-based biotechnology will have significant impact on blue bio-economies, beyond raising awareness. There are some signs, however, that the combination

of algal bio-technology and future generations of smart materials could lead to sturdy and self-healing ship hulls, offshore infrastructure, tunnels and pipes, reducing the amount of incidental spills and accidents.

The plantation-based biotechnologies, e.g. seaweed, currently have the clearest avenues of integration into current technologies in regards to closed-loop production processes, and as parts of degradable plastic replacements. Here, the ocean as a vulnerable and ever-connected plantation site comes into effect. Macro algae, that is seaweed, is relatively easy to plant and harvest. More delicate species with application in construction and furniture, like eelgrass, still need effective replanting techniques. From an environmental point of view this is clearly worth investing in, but since marketable derivatives are still lacking in scope and even concept, this area seems doomed to the slow progress (and decline on a large-scale) of academic efforts (see **Case #7: NOVAGRASS**).

ENERGY GENERATION

When we expand the look on biotechnology to include bio-refineries, the potential increases. Current technologies of biogas and -fuel are currently not compatible with high-output industrial engines like ships and airplanes. The next generation marine biogas might just do that. If the plantation of macro algae is self-sustaining, it could lead to carbon-neutral combustion fuel, although current algae-based biofuels have yet to cross the net-positive barrier in terms of carbon footprint.[42]

In this field we find mostly the optimization of current renewable energy (wind, solar, wave), and we might see a move from bottom-fixed structures to floating structures as the technologies become more durable and flexible. This would be a logical next step for Danish renewable energy, although public regulation is currently dictating (and stifling) any radical developments (and experiments) in this field and biogas. Floating power plants might eventually support fully floating infrastructure for both scientific and industrial purposes, although large-scale inhabitation would put further strains on supply chains.

Depending on the development of fuel cell technology, ocean water might be a central component of fuel sources of the future. Innovations in desalination looks to eliminate the toxicity of the brine waste. If current developments in salt-based batteries shape up, we could see a combination of desalination with battery technology.

REMEDIATION AND PRESERVATION

As described in the **BLUE TECHNOLOGY TRENDS** section, innovations of this type has seen a sharp increase in recent years due to the visual presence of plastic pollution. It should be noted that most of the identified cases either seek to remove plastic pollution through mechanical devices or to utilize said plastic in consumer or industrial products. Unfortunately even the most generous scenarios for these solutions do not come close to scaling to a volume that matches the 8 million metric tons (and growing) of plastic entering the oceans every year. Thus the best solution in the preservation category seems to be those that support the removal of plastic and other pollutants before they even reach the oceans.

As for directly regenerative technologies, we see the first steps in transplanting marine species (corals, seaweed). Should these efforts be automated it would provide an important tool in recovering devastated coastal ecosystems. It would undoubtedly be a costly development with modest financial profitability, but the environmental benefits in terms of biodiversity, water quality, bio-economy resilience, and possible ecotourism would be greater than most other technology types discussed in this report. To hammer the point home, even the most successful implementation of automated regenerative drone-fleets would still only cover relatively shallow waters, like the Baltic Sea. The average depth of the world's oceans is around 3.7km, and it is virtually impossible to imagine any regenerative interventions that would scale up the incredible volumes of our oceans. On the other hand, those immense ecosystems might well be able to regenerate passively, if we are able to halt and reverse the trajectories of mismanagement that currently characterize our relation to marine bio-economies.

The ultimate scenario, which is probably at least 40 years from now, for scalable regeneration would be autonomous underwater robots with sophisticated analytics to discern fish from plastic, fueled by the debris they collect, slowly synthesizing valuable minerals and bringing them to surface stations at 'rare' intervals. This would require the absolute best case scenarios of every single technology type coming together in a synergistic solution. It is clearly a moonshot idea, but outlining the most optimistic outliers is necessary to an exploration like the present horizon scan.

07

PERSPECTIVES VIA SELECT BLUE STARTUP CASES

PERSPECTIVES VIA SELECT BLUE STARTUP CASES

The following section presents 7 strong cases, which have been selected based on the uniqueness and scalability of their innovation as well as their potential for positive impact on blue bio-economies.

PERSPECTIVES VIA SELECT BLUE STARTUPS

CASE #1
Berring Data Collective (DK)

WHAT THEY DO:

Berring Data Collective has developed a durable and automatized sensor that is integrated into industrial fishing equipment of all sizes and types. The sensors gather valuable data on water quality, temperature, salinity, as well as catch statistics. The data is automatically uploaded to cloud servers, aggregated, analyzed, and made available to climate- and ocean researchers, public entities, and select industry players. The data is purchased by other actors, making the sensor free to install for fishermen while providing a diversification of revenue in addition to information on more efficient fishing grounds.

WHY IT APPLIES TO DK:

- This innovation addresses several issues relevant to Danish marine bio-economy.
- The IoT devices generate vast amounts of valuable subsurface data used to monitor the results of local efforts to improve ecosystem sustainability, from water quality to marine flora and fauna. The system also measures the effects of climate change and can be part of developing an international knowledge pool in the field.
- The sensors can generate data on the composition and health of specific fish schools, facilitating more efficient operations for fishermen carrying the equipment, and simultaneously limiting overfishing in vulnerable ecosystems.
- For fishermen struggling to maintain livelihoods through dwindling fish populations and tightening regulation, these sensors can provide a secondary stream of revenue.

HOW THEY SHAPE THE FUTURE:

- Once the networks of sensors have been established and yield positive results, it is fairly straightforward to include other types of data gathering, expanding the maps to benefit scientific research and potentially more industries.
- Besides fishing gear, sensors can be fitted to vessels, buoys, off-shore infrastructure, and so on, in order to extend the scale of data generation. When combined with satellite data and AI analytics, it might provide cloud-accessible real-time maps of fish activity and the health of larger marine ecosystems (see **HeraSpace**).

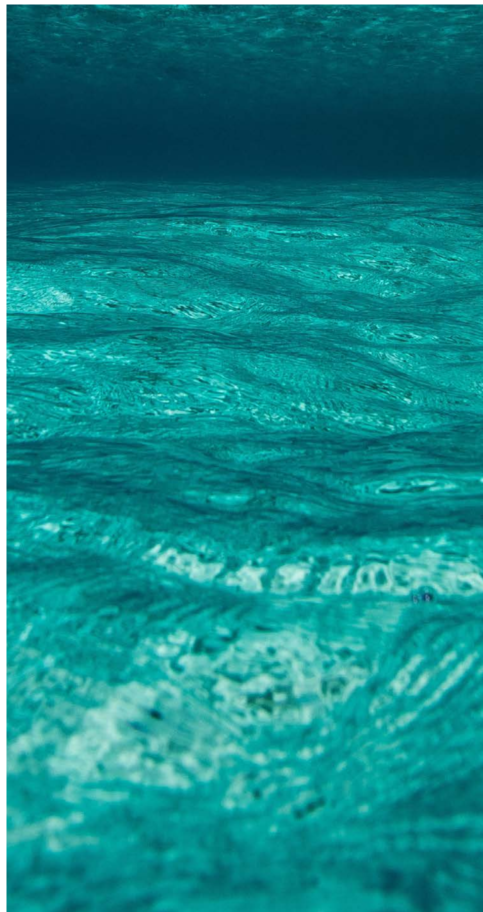
PERSPECTIVES VIA SELECT BLUE STARTUPS

CASE #1
Berring Data Collective (DK)

- The last 10 years of digitalization have shown that where data compounds, effective solutions follow. Creating an IoT network of sensors might seem an innocuous innovation, but it could very well be the first step in a revolutionary acceleration of sustainable ocean technologies.
- The sensor technology could be combined with drones or automated subsurface vehicles of the future. This should be the beginning of mapping a world that is still largely unexplored (according to NOAA, 80% of the oceans are still unmapped and unobserved).[43] In other words, we know a great deal more about the surface of Mars than we do about the ocean floor.
- As previously mentioned, it his hard to implement digital solutions in blue bio-economies. A digital mapping of marine ecosystems would come close however, scaling globally in proportion to public awareness and financial commitment, rather than human resources and market profits. This is currently a rare way for a Danish innovation to have a digitally scalable impact on the sustainability of marine ecosystems.

BARRIERS FOR GROWTH ACCORDING TO THE COMPANY:

- The largest challenge is the complex way in which marine science and ocean monitoring is funded. It is a long and convoluted chain of communication between the scientist in need of data for research, Berring Data Collective who provides the data, and the EU offices in Brussels that are likely to fund the science. The EU processes are particularly slow compared to sources from the US, from which funding arrive markedly quicker.



CASE #2
Blueye Robotics (NO)

WHAT THEY DO:

Blueye Robotics have developed a subsurface drone weighing under 9kg and small enough for regular use by non-professionals. It is powered by a chord and can reach depths of 150m, is easily controlled by a user-friendly tablet interface, and has integration with VR-goggles for extra immersion. The small form factor and advanced camera make the drone useful for underwater inspection of aquaculture plants, ships, infrastructure, and complex research operations, significantly decreasing the operational costs of such industries or public efforts.

WHY IT APPLIES TO DK:

- Easily piloted drones could form the basis for new forms of eco-tourism, providing immersive experiences of accessing shipwrecks and marine environments.
- Underwater inspections of coastal and offshore infrastructure, bridges, ships, and research stations done by human divers is extremely costly and requires skilled personnel. This drone equipment facilitates drastically reduced costs for all of these activities.
- With the proliferation of mass-market drones, the general public will see a steadily increasing flow of imagery from Danish coastal and ocean environments, removing the key barrier of visibility from the efforts towards green transformation.
- The inspection of aquacultural facilities and vulnerable ecosystems will not only be significantly cheaper, it will also be less invasive and destructive than traditional human inspection.
- With certain modifications, the innovation may provide the key to finally mapping and potentially disabling some of the 130.000 sea-mines still present in the Baltic Sea.[44]

HOW THEY SHAPE THE FUTURE:

- Simple optimizations could remove need for a tether, further extending the reach and mobility of the equipment, making it suitable for enclosed and dangerous areas like shipwrecks and submerged caves.
- Drone technology synergizes heavily with current sharing economies and Product-as-a-Service models along with the described trends of community activism. Imagine a gamified community platform where you rent a remote underwater drone or support a specific pilot, exploring and identifying certain points of interest, potentially even providing interventions through

CASE #2
Blueye Robotics (NO)

trusted users. This could lead to digital-actual crossovers of ethical massively multiplayer 'games' performing community service, livestreamed to and financed by specific communities, not necessarily defined by locality.
- The innovation synergizes well with current developments in robotics, potentially removing the need for human expertise in both deployment and control.
- If combined with full automatization (like the autonomy of self-driving cars, the diagnostics of modern medical robots, and the coordination of aerial drone fleets), this could scale any of the aforementioned applications, making human inspection and intervention in marine environments proportional to public awareness and economic investment rather than human resources and cumbersome skill- and time-intensive efforts.
- When drones become truly widespread, the technology easily synergizes with sensors akin to those from **Case #1: Berring Data Collective**, providing even more detailed 3D maps of specific and sensitive areas. To reiterate: where the data is, innovative solutions flow, especially if the aggregated systems of data are AI supported.

BARRIERS FOR GROWTH ACCORDING TO THE COMPANY:

- One of the major challenges that Blueye Robotics is experiencing is the discrepancy between their own business model and that of their customers. The large companies they work with are typically signing service-contracts with smaller companies, who then conduct both the monitoring and the data collection possible with underwater drones. However, the current business model of Blueye Robotics is not a product-as-a-service model, but based on sales of their product with the large companies doing the actual monitoring themselves. More and more market-leading companies are nonetheless starting to do their own monitoring, so the hope is that the market will follow.
- The other major barrier is the time it takes for the businesses Blueye Robotics work with to embrace new technology and adopt it - changing the modus operandi of data collection and monitoring work internally.

CASE #3

Swedish Algae Factory (SE)

WHAT THEY DO:

With a circular economic approach to marine resources, Swedish Algae Factory cultivates certain algae species making use of the emissions of nitrogen and carbon dioxide from other industries. Besides cleaning the used water of surplus chemicals that can damage shallow oceans (like the Danish seas), the biomass of algae is rich in nutrients and oils that can be utilized in various industrial food chains. Simultaneously, an offshoot of the production process creates a nano-scale shell material that interacts with UV radiation. When applied as a coating it significantly increases the efficiency of solar cells (60% for certain types).

WHY IT APPLIES TO DK:

- Excess nitrogen are one of the main threats to Danish marine environments.[45] By running wastewater through a process like Swedish Algae Factory's, emissions could be diminished.
- A central aspect of a healthy Danish bio-economy is the embrace of advanced technological solutions that strengthen circular resource systems. The nutrients from algae can be applied in industrial food production, especially aquacultural systems, decreasing costs for foodstuffs while improving the nutritional profile.
- The leading position of Danish companies as innovators and suppliers of renewable energy can be boosted through optimized solar panels. Initial research suggests that panels designed with the algerial nano-coating in mind gain up to 60% increased energy uptake.[46]
- Even though the innovation is still in its early stages, application possibilities have opened in several separate sectors (waste management, food, and energy production). Other startups in marine biotechnology display similar multi-functionality (for example **Algae Pro** and **Seagrass Tech**). If the trend continues and sufficient development is employed, algae farming might prove a stepping stone for 21st century breakthroughs and support a new basis for circular product development.

HOW THEY SHAPE THE FUTURE:

- The potential of marine biotechnology (especially algae farming) is hard to grasp and harder yet to overstate. The simplicity and efficiency of marine micro-flora and -fauna is still not fully understood.
- Algal products have high amounts of protein and lipids, macronutrients needed in famine-stricken regions of the world. Simultaneously they contain various types of vitamins and minerals usable in super-food supplements for developed countries. While algal powders are currently an ill-fitted niche product, they could easily have mass-market integration and appeal - especially considering the circular resource chain.
- If we consider the possibilities of dedicated bio-refineries, a slew of new options appear, including liquid starch- and protein products, integratable to all manners of food production, as well as biodegradable plastic replacements.
- Marine-based biotechnology also shows diverse medical properties, with new enzymes,

CASE #3
Swedish Algae Factory (SE)

injectable band-aids, and 6 new types of antibiotics already in development.

- Innovations in this field are sure to have extreme synergies with the budding research into the overlooked importance of the human microbiome (gut-flora), including potential treatments for obesity, depression, anxiety, several age-related diseases, and other major life-quality illnesses.
- The specific production process of Swedish Algae Factory also shows a promising synergy with the increased need for sustainable waste disposal in several sectors, industrial as well as in public sanitation.
- With the increased proliferation of sensors and AI-mapping described in **Case #1: Berring Data Collective** and **Case #2: Blueye Robotics**, we are sure to know a lot more about water quality and (bio-)chemical levels in the near future. In 20 years, we could see automatized dispensing of water-cleaning algae-based bio-chemicals into specific environments to counteract chemical imbalances.
- The innovation can potentially be combined with the development of flexible solar panels, integrating highly efficient electricity capture mechanisms into a host of consumer products and infrastructure - thus supporting a constantly powered and digitized society.

BARRIERS FOR GROWTH ACCORDING TO THE COMPANY:

- Legislation and bureaucracy is a major barrier. In Sweden it is not possible to retrieve permits for setting up algae farms at sea, which has forced Swedish Algae Factory to grow it on land. At the same time, fish farms are nonetheless only legal when ocean-based. This results in huge quantities of excess nutrients from the fish farms either going to waste or flowing into surrounding waters, polluting local ecosystems with detrimental effects. Swedish Algae Factory has identified a great potential in filtering the water from fish farms, using the excess nutrients to grow algae and avoiding the pollution of waters. However, due to the current legislation, applications to set up algae farms at sea or start land-based fish farms have not been approved.
- Swedish Algae Factory cater in large part to the chemical industry. Convincing the industry that it is possible to develop a clean product without synthesizing it is a huge challenge. There is a need within the chemical industry for accepting that you can have reproducible results when growing algae, and that you can grow it with a high yield. As more large companies work with Swedish Algae Factory, this has brought legitimacy to their work.
- Investors are more likely to invest in companies with fast growth-rates. As has been highlighted earlier, for many ocean technology companies, this is nonetheless difficult making it harder for them to attract investments - this has also been the case for Swedish Algae Factory. However, largely due to the widespread public attention on the issue of plastics in the ocean, the company is experiencing increased interest.

PERSPECTIVES VIA SELECT BLUE STARTUPS

VAN PLESTIK

CASE #4
VanPlestik (NL)

WHAT THEY DO:

VanPlestik are repurposing end-of-life plastic waste into a high quality 3D printing filament. Having a commercially viable outlet for the plastic collected from the oceans will incentivize more efficient cleaning systems and ultimately speed up the regeneration of marine ecosystems. 3D printing as a technology will only increase in sophistication, but currently a number of household items and furniture can be made from ocean plastics, as well as bespoke parts for tools and machines. Increasingly, 3D printing capabilities will be accessible in more remote areas, where plastic pollution is coincidentally the worst. This essentially decentralizes the whole production chain, putting less strain on global transportation systems.

WHY IT APPLIES TO DK:

- The majority of plastic waste from beaches, landfills, or directly from recycling systems can be upcycled into individualized parts for industry machinery and consumer products.
- Improved re-usability of Danish consumer waste allows a decrease in ecological footprint, which is currently one of the worst per capita in Europe.[47]
- Production capabilities will be increasingly automatized, gradually moving the workforce demands from production to employment of designers and corporate communication specialists, coinciding with the current trends in demographics of the Danish workforce.
- Localized production decreases the need for maritime transportation, forcing a dominant industry to seek out sustainable sources of revenue.

PERSPECTIVES VIA SELECT BLUE STARTUPS

VAN PLESTIK

CASE #4
VanPlestik (NL)

HOW THEY SHAPE THE FUTURE:

- Decreased worldwide transportation means less CO_2, less noise pollution of marine environments, less wrecks and spills, among many other benefits.
- Open-source product recipes decentralizes the production process, negating global inequality.
- Innovations in 3D printing can synergize with other marine resources. Printing filaments can be made of seaweed or other biological materials like hemp, further decreasing the reliance on plastics for consumer products.
- 3D printing can even be combined with food production (like Upprinting Food), paving the way for considerable synergies with the marine bio-tech innovations in nutrition and medicine.
- The biggest potential innovation eventually lies in the digital open-source distribution of recipes and production methods, scaling the technology and circular production of tools, building materials, marine-based superfoods and medicine across the globe.
- Upcycling into 3D printing can also encompass construction debris, like Concr3de that has made a prototype of a Notre Dame gargoyle, literally incorporating limestone and ash from the recent fire in the reconstruction.
- In 20 years, we will see considerable synergy with AI creating novel design-concepts, with AI design and 3D printing entering the fields of advanced engineering and construction of all sorts of urban, coastal, and maritime vehicles and buildings.

BARRIERS FOR GROWTH ACCORDING TO THE COMPANY:

- Many different types of plastics exist, and it is currently not possible to 3D print with every type of plastic. Thus, the sorting of plastic is a necessary but resource demanding first step in this process. The difficulty in recycling the many different types of plastic is a problem relevant not just for VanPlestik but worldwide.
- VanPlestik identifies themselves as a social enterprise, with their main focus evolving around doing good and making a change rather than on making profits. Every activity is thus assessed in accordance with the value it creates in society, not how it scales the company, which does constitute a barrier for growth.
- Additionally, continuous R&D is required for further developing and improving their technology of 3D printing with recycled plastics, making fast growth difficult.
- As the price of virgin-plastic products is very low, most people have a wrong idea of what a recycled plastic product should cost. This makes it hard to convince customers that the price of the 3D printed product is fair and thus compete in the market.

CASE #5
BlueBenu (DK)

WHAT THEY DO:

BlueBenu has developed a container-sized modular production unit (MPU) that transforms plastic waste into crude oil and additionally refines the oil into low emission eco-fuel usable by current combustion engines in e.g. ships and planes. The system is decentralized and thus provides a way for communities around highly polluted coastal areas to organize and monetize the collection of end-of-life plastic waste. Unlike current plastic recycling systems, BlueBenu's innovation works with so-called mixed waste, that is many different types of plastics mixed with organic material, like food waste or marine bio-material. Their solution virtually closes the value chain into a loop providing a host of beneficial derivative effects at several levels (environmental, social, and economic).

WHY IT APPLIES TO DK:

- This innovation could provide an avenue to greater sustainability for the maritime shipping sector, one of the most polluting industries. Danish shipping makes up a significant part of worldwide maritime traffic, and achieving momentum in the sustainability transformation is a monumental prize - not only for environmental reasons, but also as a business case.
- The technology could provide a demand for plastic waste as the first step in a new value chain, significantly increasing incentive to remediate oceanic plastic pollution.
- Likewise, the innovation provides a use for any plastic trash collected (including mixed waste), making trash collection less of a net financial negative.
- With a decentralized production unit, the drive for clean-ups could shift from central municipalities to peripheral communities. This would have a significant positive impact on remote communities in e.g. Greenland, where state support for environmental remediation is hard to actualize.

CASE #5
BlueBenu (DK)

HOW THEY SHAPE THE FUTURE:

- If implemented at large scale, the technology could mean a significant decrease in shipping emissions of both greenhouse gasses and particle pollution.
- The monetization of plastic waste may decrease the amount of pollution ever reaching the oceans, since the plastic is more concentrated before spreading into the ocean. As mentioned, 10 rivers contribute a staggering 90% of the oceanic plastic pollution,[48] an organized effort to collect and repurpose that plastic could have great positive effects.
- BlueBenu's MPU simultaneously provides an incentive to collect existing plastic debris, especially in low-wage regions, where plastic pollution coincidentally accumulates.
- The decentralized and modular units scale well in volume and to peripheral regions, negating global inequalities.
- The community aspect of the innovation synergizes well with trends in local activism and eco-tourism.
- In areas without a realistic community component (and far from shorelines), the technology synergizes with recently popularized efforts in automated ocean cleaning (like **The Ocean Cleanup**]). In the future, these efforts should be strengthened by drones and real-time maps of plastic pollution.
- Depending on the profitability of the produced eco-fuel, the innovation has a clear synergy with global waste-trade platforms (like **Waste Outlet**) that will become ubiquitous in a few years.

BARRIERS FOR GROWTH ACCORDING TO THE COMPANY:

- BlueBenu defines itself as a cleantech company. In cleantech, which is largely research-based, there is a need for very large initial investments in order to test and develop the product in its early stages. Equipment, laboratories, and personnel is additionally more expensive than in many other fields of work. In terms of scalability, the growth-process is thus slow, as large income or continuous investments are needed.

CASE #6
NoBriner (DK)

WHAT THEY DO:

NoBriner aims to revolutionize the desalination industry by offering an ecologically harmless way to manage and handle reject brine. Brine is a toxic byproduct of desalination regardless of the operating factories' scale. Current methods involve dilution, discharge, or (ground)storage, all of which damage the environment heavily. In addition to pollution, discharging brine back into the ocean raises the overall salinity of the oceans, with severe consequences for marine biology in addition to a decreased efficiency of the desalination plant.

NoBriner's innovation consists of a machine that converts this toxic waste to a commodity product, namely salt. For community-level users this creates local jobs for the workforce with the promise of related skills training. The second part of NoBriners service involves handling the end product of the brine management processes, which they sell to their partners, ensuring that profits come from commercial clients and not by exploiting communities' needs.

WHY IT APPLIES TO DK:

- This innovation holds potential to secure future sources of drinking water from chemical pollution, e.g. excess nitrite, in a low cost way. The current alternative is reverse-osmosis, which is a fairly costly process.
- The issue of securing our drinking water in the face of climate changes is highly pertinent. Dry years like that of 2018 forced farmers to use an additional 330 million cubic meters of groundwater on irrigation. This puts groundwater reserves under great pressure. If industries will not reduce the amount of water used and suffer the consequent economic losses, which is unlikely, groundwater reserves risk depletion in the long run. Thus, new sources of high-quality water only becomes more necessary when faced with the possibility of many more summers of drought.
- It is crucial to develop key innovations before the need becomes critical if in any way possible - with the added option of providing skilled developmental aid to regions where lack of clean water is already critical. However there is a need for research done within the use of reject brine.
- Ecologically harmless brine can be used in aquaculture to irrigate salt tolerant species (300% increase in biomass),[49] or to generate electricity.
- The process can potentially (with significant technological development) yield valuable metals and salts used in agriculture and various industrial products (that are hard to get in DK).[50]
- The innovation also holds the possibility of marketing speciality products - a modern version of Læsø's Sydesalt for example.

CASE #6
NoBriner (DK)

HOW THEY SHAPE THE FUTURE:

- Lack of fresh water is estimated to be one of world's largest challenges in this and next century.[51] Nobriner offers a localized solution.
- NoBriner also synergizes with trend in local activism and community efforts, especially in subtropical climate zones.
- Reject brine is a rising problem - 16.000 desalination plants exist worldwide,[52] producing 142 million cubic meters of brine every day.[53] Thus, the scale is extreme and the demand for fresh water is only increasing, making NoBriners solution highly relevant.
- The innovation additionally synergizes with real-time mapping of water quality and salination, since most brine is discharged into oceans near plants, significantly increasing local salination.

BARRIERS FOR GROWTH ACCORDING TO THE COMPANY:

- The biggest challenge is the lack of research within sustainable uses of brine. Large companies within the field are not researching on the matter, leaving NoBriner to do the research themselves - which is both time-consuming and expensive, slowing their development. NoBriner has at times faced issues of credibility also because of the lack of research in this space.
- NoBriner's desalination machine can currently only process relatively small quantities of brine at a time, making research even more pertinent as new insights are needed in order to develop a machine that will allow for the type of large-scale operations needed in a foreseeable future when lack of drinking water becomes critical.

CASE #7
NOVAGRASS (DK)

WHAT THEY DO:

NOVAGRASS is a consortium of private companies and universities, and thus the odd one out in the case selection. They develop innovative techniques for harvesting of seagrass seeds, optimal nursery and storage, as well as planting under different environmental conditions. Additionally they monitor the health of eelgrass ecosystems, while developing equipment and effective techniques for large-scale restoration. The project sets industry standards for eelgrass restoration under different environmental and climatic conditions.

The NOVAGRASS project was terminated in 2018, as the funding stretched for 5 years. The project of planting eelgrass is continuing in two new projects, TRANSPLANT and SANDCAP.[54] While the academic basis of the project undoubtedly is what made it happen in the first place, the short time-scale of such academic projects also show the inherent limitations in leaving regeneration innovation purely to non-commercial actors. Ultimately, with the end of the NOVAGRASS project the process of lifting innovation from academia to the market risk having to start all over again. In the future a greater focus should be put on the need to secure that commercial actors have the opportunity and know-how to carry on sustainable bio-economic projects such as NOVAGRASS after the academic project terminates.

WHY IT APPLIES TO DK:

- As mentioned, excess levels of nitrogen and phosphorus are among the key concerns for Danish marine ecosystems. Healthy seagrass meadows effectively combat these chemical imbalances while providing habitat for numerous marine species (and indirectly birds), while also decreasing coastal erosion.
- Eelgrass has traditionally been used for construction, furniture, and new startups are currently innovating its uses (such as **Zostera**, **MoenTang**, and **Nikolaj Thrane**). A renewed demand should lead to an increased focus on restoration methods.
- The NOVAGRASS case is an example of an explicit full spectrum regenerative technology with benefits for water quality, the sea-bed, floral and faunal biodiversity below and above the surface, and with business potential.
- While eelgrass only grows until 5-7 meters depth in Denmark, it can grow in depths up to 50 meters in other seas. Thus eelgrass has a relatively large scaling potential for a locally specific technology.

CASE #7
NOVAGRASS (DK)

HOW THEY SHAPE THE FUTURE:

- Eelgrass can help solve the problem of excess levels of nitrogen and phosphorus going from land into the ocean in any place on the planet that eelgrass can grow.
- It synergizes with the above mentioned innovations in construction and design.
- In a 10 to 20 year horizon, we could see multi-synergies with Product-as-a-Service models, drone technology and robotics, as well as community-based activism, where autonomous underwater vehicles enable scalable plantation of eelgrass possibly combined with gamified community platforms, where trusted users might even provide interventions.
- The only innovations we have come across that are directly regenerative have been transplanted or simulated coral reefs - and this innovation.[55]
- It showcases the fact that any explicitly regenerative efforts are currently almost exclusively within academic efforts. It may be due to the novelty of the field, or because of antiquated conceptions of the commercial viability of marine regeneration (and concurrent production).
- This points to considerable potential in accelerating the commercialization of innovations from academic efforts in this field. Likewise a much needed support from private actors to speed up research processes.

BARRIERS FOR GROWTH ACCORDING TO THE COMPANY:

- The universities involved in a project such as this are not responsible for the future restoration of eelgrass as such. Their academic responsibility lies in doing the research that might enable such restoration. As such, it is not the aim of the universities to create a sustainable business model based on the replanting and further commercial use of eelgrass; this is left for the commercial actors. For the future, a greater focus should be put on the need to secure that commercial actors have the opportunity and know-how to carry on sustainable bio-economic projects such as NOVAGRASS, once the academic project ends.

08

CONCLUSION

CONCLUSION

For several years, GREEN INNOVATION GROUP has been involved in shaping the approach on how to solve the equation of growth and sustainability by mapping sustainable innovation, analyzing the trends and potentials within the verticals, as well as facilitating the connection between frontier innovation and established actors from the private and public sector.

This horizon scan is providing a fact base and platform that enables sound decision making and empower the reader by organizing and visualizing a highly complex ecosystem of innovation in constant motion.

The blue bio-economy concept is one that provides an opportunity to combine sustainability and growth, such as using and reusing natural capital as efficiently as possible and finding value throughout the life cycles of finished products, which can boost company profitability and national resource productivity.

This horizon scan has explored the blue bio-economy through four different lenses. **Firstly**, in section 3, it has mapped the ecosystem for blue innovation in Denmark. **Secondly**, in section 4, it has mapped the technologies that are dominant and will continue to dominate in the field. **Thirdly**, the horizon scan has taken a shot at predicting the future of blue innovation by analyzing the technological trends that became apparent after the thorough mapping in sections 3 and 4. **Fourthly**, the horizon scan aims at making a light assessment of the potential for environmental impact, informing the work of enabling the transition to a regenerative blue bio-economy.

We hope this horizon scan and the supporting fact base will inspire action to address the challenges and capture the opportunities of growing the blue bio-economy.

APPENDIX

APPENDIX

METHODS & APPROACH

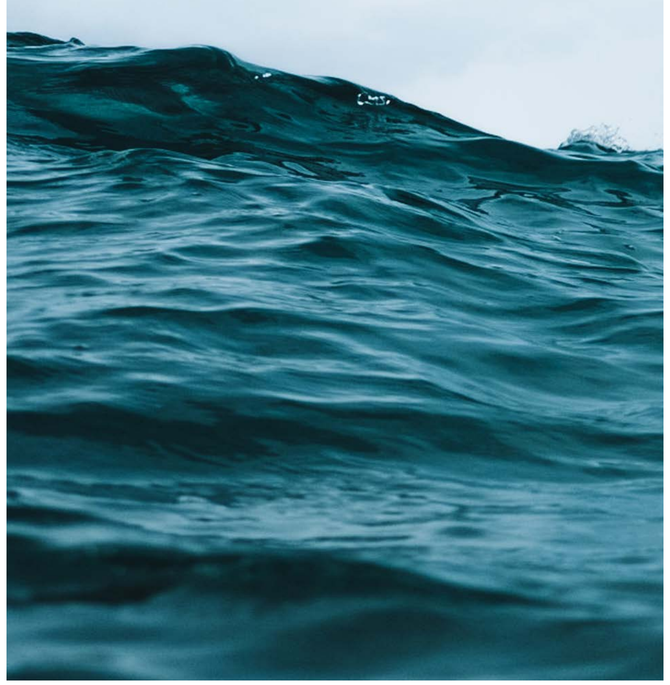
At GREEN INNOVATION GROUP, we have mapped 4000 impact innovations and gathered extensive data on the key companies that are on the frontier of sustainable innovation. This information cannot be found in registers and is next to impossible to gather. Most startups are not listed on the stock exchange or in company registers; if they are, the data is often outdated considering the double to triple digit growth rates a company can experience in the early years. Due to the ever changing nature of innovation, startup companies' changing states and circumstances mean that they can quickly turn from explosive growth to sudden threat of bankruptcy, or the other way around.

The portfolio of startups is available through BIFROST, a platform GREEN INNOVATION GROUP has developed to contain all relevant information on the companies that can impact the future of the planet. BIFROST is also used to match innovators with private and public clients. Through this platform, GREEN INNOVATION GROUP has mapped up to 80% of the estimated total number of startups working with sustainability[56]. Of those companies, around 1200 have detailed profiles, and GREEN INNOVATION GROUP has identified 121 innovation cases working with ocean technologies for a better world. A multi-layered mapping of these cases is presented in this report.

The extensive quantitative data is ideal for creating the innovation maps in this horizon scan. We combine that data with careful qualitative research and analysis to create qualified predictions for the trends in innovation and impact within each area of interest. We look at the innovations currently on the horizon and look at various scenarios for how those innovations synergize with other technologies currently in development. Ultimately we try to assess the potential positive impact that key innovations may have on blue bio-economies, and make our conclusions based on these predicted scenarios. This combination of quantitative data and qualitative analysis is what makes up the present horizon scan.

It is our intention to create an ambitious and realistic look into the future of sustainable ocean technologies. Working with startups and innovation is clearly a field characterized by constant change and sudden shifts, and the future is certain to provide surprising developments. However, we are confident that the present horizon scan will provide VELUX Foundation with at least 3 valuable assets:

1. A comprehensive overview of the current landscape of innovations within sustainable ocean technologies.
2. Useful tools to help navigate the constantly evolving scene of sustainable entrepreneurship as well as the technology types that are sure to shape blue bio-economies in the future. Knowing which innovations to support, which to keep an eye on, and which to be sceptic of, is crucial to an efficient green transformation.
3. A catalogue of ideas and their contexts that can inform continued efforts towards healthy marine ecosystems - both on a strategic and a practical level.



DEFINING RELEVANT CONCEPTS

The following concepts are necessary to clarify in order to ensure a clear understanding of the present analysis and its conclusions.

STARTUP

This report leans on the definition of startups given by Paul Graham:[57]

"A startup is a company designed to grow fast. Being newly founded does not make itself a company and startup. Nor is it necessary for a startup to work on technology, or take venture funding, or have some sort of 'exit.' The only essential thing is growth. Everything else we associate with startups follows from growth."

A company is therefore not necessarily defined as a startup just because it is new, small or has few employees, but is defined as a startup when the company has a considerable potential for growth. This report thus defines startups as

young and fast growing companies that have not yet established themselves in the market. These companies have a constant need for reaching out to partners to support their development and to ensure they establish themselves.

GREEN COMPANIES

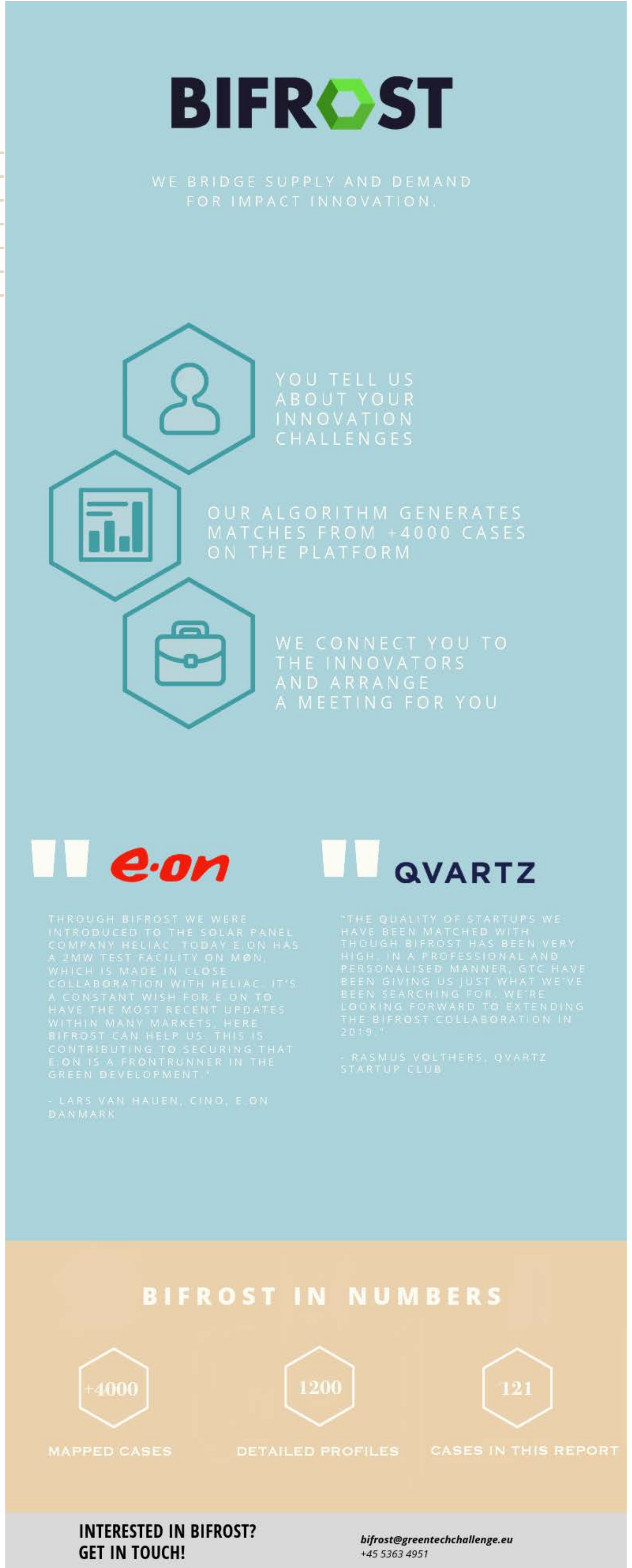
GREEN INNOVATION GROUP defines a green company as a company that has a positive influence on the world's environment and/or climate every time they sell a product or service. Thus, the definition includes a series of different industrial sectors – everything from energy, information technology, and resource management to food technology, and mobility.

INNOVATION

Along the lines of the Merriam-Webster dictionary, we define an innovation as a new idea, creative thoughts, new imaginations in form of a device or method.[58] More generally, GREEN INNOVATION GROUP takes an innovation to signify the application of better solutions that meet new requirements, known or unarticulated needs. In this vein, 'innovation' is sometimes used interchangeably with 'technology' to signify not only the specific technological development, but also the implications of its broader integration to society. Innovation takes place through the provision of more-effective products, processes, services, technologies, or business models that are made available to markets, governments, and society. An innovation is something original and more effective and, as a consequence, new, that "breaks into" the market or society.[59]

BLUE BIO-ECONOMY

A bio-economy usually references a bio-based economy. GREEN INNOVATION GROUP uses the term with a slightly wider definition, encompassing the conceptual overlap between a 'natural' ecosystem and the (human) economical aspects intertwined with that ecosystem. This should capture our fundamental sentiment that biological ecosystems are always the basis of our economy, which in turn always have an effect on ecosystems. We use the descriptor 'blue' to qualify an innovation or bio-economy as pertaining to the marine and maritime in combination, rather than only the latter as it is sometimes used. Again this is done to underscore the interconnectedness of oceanic environments as well as human activities in and around the oceans.



END NOTES

1. Søfartsstyrelsen (2017). Det Blå Danmark: https://www.soefartsstyrelsen.dk/Presse/temaer/DetBlaaDanmark
2. IUCN (2016). Ocean Warming: https://www.iucn.org/resources/issues-briefs/ocean-warming
3. NOAA (2019). Ocean acidification: https://www.noaa.gov/education/resource-collections/ocean-coasts-education-resources/ocean-acidification
4. Andre Freiwald et.al | UNEP-WCMC Biodiversity Series (2004). Cold-water Coral Reefs: Out of Sight – No Longer out of Mind: https://archive.org/details/coldwatercoralre04frei
5. KTC (2018). Se mulighederne i havmiljøets trusler: https://www.ktc.dk/artikel/se-mulighederne-i-havmiljoeets-trusler
6. Aarhus Universitet - DCE (2015). Status og muligheder for det danske hav.
7. Sheba (2017). Sustainable Shipping and Environment of the Baltic Sea region (SHEBA): https://www.sheba-project.eu
8. Oceana (2016). Towards the recovery of European Fisheries: http://eu.oceana.org/sites/default/files/towards_the_recovery_of_european_fisheries_fv.pdf
9. Anton Geist | Information (2017). Kvotekonge-skandalen og DF's følelser: https://www.information.dk/debat/leder/2017/08/kvotekonge-skandalen-dfs-foelelser,
   Miljø- og Fødevareministeriet (2018). Udkast til Danmarks Havstrategi II.
10. Naturstyrelsen (2014). Danmarks Havstrategi Miljømålsrapport.
11. Maersk (2019). Our sustainability strategy: https://www.maersk.com/about/sustainability/our-sustainability-strategy
12. WWF (2015). Havet skal beskyttes bedre: https://www.wwf.dk/?11440
    Magnus Bredsdorff | Ingeniøren (2019). Kritiske tal for vandmiljø gemt af vejen med nøje orkestrerede krumspring: https://ing.dk/artikel/kritiske-tal-vandmiljoe-gemt-vejen-med-noeje-orkestrerede-krumspring-223386
    DR - Midt og Vestjylland (2019). Millioner til nyt projekt: Naturvenner opruster indsats under havet: https://www.dr.dk/nyheder/regionale/midtvest/millioner-til-nyt-projekt-naturvenner-opruster-indsats-under-havet
13. Maritime Danmark (2018). 22.000 beskytter havmiljøet: https://maritimedanmark.dk/Mobil/?Id=39498
    Avisen.dk (2019). Danskerne er vilde med at fjerne plastikaffald i vandkanten: https://www.avisen.dk/advertorials/ritzauinfo/danskerne-er-vilde-med-at-fjerne-plastikaffald-i-van_545071.aspx
14. The Arctic Institute (2019). A Sea of Conflict? The Growing Obsession with Maritime Space: https://www.thearcticinstitute.org/sea-conflict-growing-obsession-maritime-space/
15. Aalborg University (2018). Biogas kan bane vejen for grøn transport: https://via.ritzau.dk/pressemeddelelse/biogas-kan-bane-vejen-for-gron-transport?publisherId=8155951&releaseId=12315985
16. Fødevareministeriet (2010). Havet - en uudnyttet ressource.
17. Silvia Ferrari | Cornell University (2019). Autonomous Vehicles for Air, Land, and Sea: https://research.cornell.edu/news-features/autonomous-vehicles-air-land-and-sea
    Renee Knight | Inside unmanned systems (2017). Autonomous Vehicles Swarming the Sea: http://insideunmannedsystems.com/autonomous-vehicles-swarming-sea/
18. Danske Maritime (2019). Den Maritime Industri: https://danskemaritime.dk/danskemaritime/den-danske-maritime-industri/
19. Marta Domingues (2017). The Agile Innovation of Startups: https://www.ie.edu/insights/articles/the-agile-innovation-of-startups/
    Silicon Vally tours (2019). Why Startups Are Better Innovators Than Big Companies: https://siliconvalley.center/blog/why-startups-are-better-innovators-than-big-companies/
20. Lisa Steigertahl et.al. (2019). EU Startup Monitor: http://startupmonitor.eu/EU-Startup-Monitor-2018-Report-WEB.pdf
21. NOAA (2019). How much of the ocean have we explored?: https://oceanservice.noaa.gov/facts/exploration.html
22. Ibid.
23. Danish National Research Foundation (2019). Aftale om Pionercentrene er på plads – 1 mia. kr. til forskning i store samfundsudfordringer: https://dg.dk/aftale-om-pionercentrene-er-paa-plads-1-mia-kr-til-forskning-i-store-samfundsudfordringer/
24. Greentech Challenge (2018). ANALYSE AF DET DANSKE ØKOSYSTEM FOR STARTUPS INDEN FOR GRØN ENERGI- OG MILJØTEKNOLOGI: https://em.dk/media/12931/gtc_analyse_v17_public_lowq.pdf
25. Chris Zook | Harward Business Review (2016). When Large Companies Are Better at Entrepreneurship than Startups: https://hbr.org/2016/12/when-large-companies-are-better-at-entrepreneurship-than-startups
26. Lloyd's Register Group Limited et al. (2015). Global Marine Technology Trends 2030.
    Engadget (2018). Self-repairing material plucks carbon from the air: https://www.engadget.com/2018/10/14/self-repairing-material-uses-co2-from-air/
27. Seafood Watch (2019). Aquaculture: https://www.seafoodwatch.org/ocean-issues/aquaculture/pollution-and-disease
28. Rebecca Gentry et.al. | Nature Ecology & Evolution (2017). Mapping the global potential for marine aquaculture: https://www.nature.com/articles/s41559-017-0257-9
29. The Fish Site (2009). The potential of aquaculture: https://thefishsite.com/articles/the-potential-of-aquaculture
30. Oceana (2016). Towards the recovery of European Fisheries: http://eu.oceana.org/sites/default/files/towards_the_recovery_of_european_fisheries_fv.pdf
31. Travel Agent Central (2018). Stats: 87% of Travelers Want to Travel Sustainably: https://www.travelagentcentral.com/running-your-business/stats-87-travelers-want-to-travel-sustainably

32. Rina Chandran | World Economic Forum (2019). Why floating solar panels are on the rise: https://www.weforum.org/agenda/2019/02/in-land-scarce-southeast-asia-solar-panels-float-on-water/
33. Established players like Starbucks and H&M are increasingly decreasing plastic as part of CSR efforts.
34. World Economic Forum (2018). 90% of plastic polluting our oceans comes from just 10 rivers: https://www.weforum.org/agenda/2018/06/90-of-plastic-polluting-our-oceans-comes-from-just-10-rivers/
35. Green Sea Guard (2017). Green Sea Guard – Our Vision in Brief: https://www.rushlightevents.com/wp-content/uploads/2017/01/RUSHLIGHT-SHOW-2017-SHOWCASE-GREEN-SEA-GUARD.pdf
36. FAO (2014). Oceans crucial for our climate, food and nutrition: http://www.fao.org/news/story/en/item/248479/icode/
37. Leo Jakobson | Modern Consensus (2019). From the Congo to the open ocean, blockchain is helping companies ethically source natural resources: https://modernconsensus.com/technology/congo-ford-lg-ibm-blockchain/
38. Silvia Ferrari | Cornell University (2019). Autonomous Vehicles for Air, Land, and Sea: https://research.cornell.edu/news-features/autonomous-vehicles-air-land-and-sea
39. UST (2019). Unmanned Marine Systems: https://www.unmannedsystemstechnology.com/company/autonomous-surface-vehicles-ltd/
40. Lost fishing gear, or so called 'ghost gear' are among the greatest killers in our oceans, and not only because of their numbers. Literally hundreds of kilometers of nets and lines get lost every year and due to the nature of the materials used to produce these types of gear, they can and will keep fishing for multiple decades, possibly even for several centuries. Source: Ghost Fishing (2019). The problem: https://www.ghostfishing.org/the-problem/
41. Claire Le Guern | Coastal Care (2018). When the Mermaids Cry: The Great Plastic Tide: http://plastic-pollution.org/
42. Royal Academy of Engineering (2017). Sustainability of liquid biofuels: http://eprints.lancs.ac.uk/125260/1/RAEng_Biofuels_Report_electronic_version.pdf
43. NOAA (2019). How much of the ocean have we explored?: https://oceanservice.noaa.gov/facts/exploration.html
44. Forsvaret (2019). Danmark overtager kommandoen over NATO's mineryddere på havet: https://www2.forsvaret.dk/nyheder/intops/Pages/DanmarkovertagerkommandoenoverNATO%E2%80%99sminerydderep%C3%A5havet.aspx
45. Peter Henriksen | Nationalt Center for Miljø og Energi (2012). Hvorfor er kvælstofudledning et problem i vandmiljøet?: http://dce.au.dk/fileadmin/dce.au.dk/Udgivelser/Notat_kvaelstofudledning_i_vandmiljoeet.pdf
46. Swedish Algae Factory (2019). Solar Efficiency Enhancing Nanomaterial: http://swedishalgaefactory.com/lab/solar-efficiency/
47. Berlingske (2017). Hvis alle levede som danskerne, havde vi brug for 3,6 jordkloder: https://www.berlingske.dk/samfund/hvis-alle-levede-som-danskerne-havde-vi-brug-for-36-jordkloder
48. Patel Prachi | Scientific American (2018). Stemming the Plastic Tide: 10 Rivers Contribute Most of the Plastic in the Oceans: https://www.scientificamerican.com/article/stemming-the-plastic-tide-10-rivers-contribute-most-of-the-plastic-in-the-oceans/
49. United Nations University at Phys.org (2019). UN warns of rising levels of toxic brine as desalination plants meet growing water needs: https://phys.org/news/2019-01-toxic-brine-desalination.html
50. E.g. magnesium, gypsum, sodium chloride, calcium, potassium, chlorine, bromine and lithium. With better technology the following metals and salts could also be extracted: Sodium, magnesium, calcium, potassium, bromine, boron, strontium, lithium, rubidium and uranium.
51. Robin McKie | The Guardian (2015). Why fresh water shortages will cause the next great global crisis: https://www.theguardian.com/environment/2015/mar/08/how-water-shortages-lead-food-crises-conflicts
52. Edward Jones et al. | Science of The Total Environment (2019). The state of desalination and brine production: A global outlook: https://www.sciencedirect.com/science/article/pii/S0048969718349167
53. Ibid.
54. University of Southern Denmark (2018). Test of methods for large-scale restoration of eelgrass (Zostera marina) in coastal areas of Denmark: https://www.sdu.dk/da/om_sdu/institutter_centre/i_biologi/forskning/phdprojekter/neles,-d-,wendlander
55. Not just protecting or conserving a natural regeneration, but actively facilitating an accelerated natural restoration.
56. Estimate by Andrea Licata, Phd from International University Institute for European Studies (IUIES).
57. Paul Graham (2012). Startup = Growth: http://www.paulgraham.com/growth.html
58. Merriam-Webster Dictionary (2019). Innovation: https://www.merriam-webster.com/dictionary/innovation
59. Per Frankelius | The Journal of High Technology Management Research (2009). Questioning two myths in innovation literature: https://www.sciencedirect.com/science/article/pii/S1047831009000054

REPORTS WHICH HAVE INFORMED THIS HORIZON SCAN

Aarhus Universitet - DCE – Nationalt Center For Miljø Og Energi. 2015. "Status Og Muligheder for Det Danske Hav." Rapport Til VILLUM FONDEN Og VELUX FONDENs Miljøprogram. Aarhus Universitet, Institut for Bioscience, Aarhus Universitet, Juridisk Institut, Aarhus Universitet, Institut for Miljøvidenskab, DTU Aqua. https://veluxfoundations.dk/sites/default/files/status_og_muligheder_for_det_danske_hav.pdf.

Andersen, Peter, Høngaard, Tove Duvold, Bo Frølund, Johannes Lüneborg, Karoline Toft-Petersen, Helga Vanthournout, and Christof Witte. 2019. "The New Plastic Economy - A Research, Innovation, and Business Opportunity for Denmark." Summary of findings. McKinsey&Company.

Brackley, Aiste, and Bron York. 2019. "What's next for Sustainable Business?" SustainAbility. https://sustainability.com/wp-content/uploads/2019/01/SA-Trends2019-Full.pdf.

Danmarks Naturfredningsforening. 2018. "Danmarks Naturfredningsforenings HAVPOLITIK." https://issuu.com/danmarksnaturfredningsforening/docs/havpolitik_2018_lav.

Fødevareministeriet. 2010. "Havet - En Uudnyttet Ressource En Vidensyntese Om Danske Muligheder Indenfor Marin Bioteknologi Og Anden Udnyttelse Af Havets Ressourcer." Ministeriet for Fødevarer, Landbrug og Fiskeri. https://mst.dk/media/91729/havet_en_uudnyttet_ressource.pdf.

Global Maritime Forum, MARSH, and IUMI (International Union of Marine Insurance. 2018. "Global Maritime Issues Monitor." The Global Maritime Forum Foundation. https://www.globalmaritimeforum.org/content/2018/10/Global-Maritime-Issues-Monitor-2018.pdf.

Krzaklewski, Marian, and Patrizio Pesci. 2018. "The LeaderSHIP 2020 Strategy as a Vision for the Maritime Technology Industry: Towards an Innovative, Sustainable and Competitive Maritime Industry in 2020 (Own-Initiative Opinion)." Opinion CCMI/152 LeaderSHIP strategy. European Economic and Social Committee. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52017IE2892&from=IT.

Lloyd's Register Group Limited, QinetiQ, and University of Southampton. 2015. "Global Marine Technology Trends 2030." Download: https://www.lr.org/en-gb/insights/global-marine-trends-2030/global-marine-technology-trends-2030/

Miljø- og Fødevareministeriet. 2018. "Danmarks Havstrategi II - Første Del. God Miljøtilstand, Basisanalyse, Miljømål." Miljø- og Fødevareministeriet. https://prodstoragehoeringspo.blob.core.windows.net/5ecfd397-7cd3-432a-a8f5-5590674cb003/Udkast%20til%20Danmarks%20Havstrategi%20II.pdf.

Naturstyrelsen. 2014. "Danmarks Havstrategi Miljømålsrapport." Miljøministeriet. https://naturstyrelsen.dk/media/nst/Attachments/Miljoemaalsrapport.pdf.

OECD. 2013. "Marine Biotechnology: Enabling Solutions for Ocean Productivity and Sustainability." OECD Publishing: Organisation for Economic Co-operation and Development. https://read.oecd-ilibrary.org/science-and-technology/marine-biotechnology_9789264194243-en#page4.

Vækstteamet for Det Blå Danmark. 2017. "ANBEFALINGER Vækstteamet for Det Blå Danmark – Danmark Som et Globalt Maritimt Kraftcenter." Erhvervsministeriet. https://www.soefartsstyrelsen.dk/Documents/Publikationer/V%C3%A6ksttemaet%20for%20Det%20Bl%C3%A5%20Danmark%20anbefalingsrapport%202017.pdf.

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GREEN INNOVATION GROUP A/S