Future Exploitation of Areas Beyond National Jurisdiction

On the value of Strategic Environmental Assessment of the High Seas based on new industries and human activities

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Executive summary

Areas beyond national jurisdiction (ABNJ) make up about 40 percent of the surface of our planet and cover nearly two-thirds of the world's oceans. These areas are home to unique species and ecosystems that have evolved to survive extreme heat, cold, salinity, pressure and darkness. Furthermore, these areas represent 95% of the Earth's total habitat by volume.[1]

The legal framework for all activities in the oceans and seas is provided by The United Nations Convention on the Law of the Sea (UNCLOS) which includes provisions on protection and preservation of the marine environment. It is complemented by two implementing agreements which address matters related to the Area (the seabed and ocean floor and subsoil thereof, beyond the limits of national jurisdiction), and the Agreement for the Implementation of the Provisions of UNCLOS relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks (UNCLOS, n.d.). In addition to UNCLOS and its implementing agreements, there are a number of other international instruments that are relevant to the conservation and sustainable use of marine biodiversity in areas beyond national jurisdiction (BBNJ). However, in the last decade, the question regarding whether those instruments are sufficient to protect the biodiversity in ABNJ has arisen.

Therefore, an intergovernmental conference has been established to develop an implementing agreement to UNCLOS to ensure long-term conservation, the strengthening of regulation and the sustainable use of marine resources in ABNJ *The geographic scope of the new BBNJ-agreement will be ABNJ i.e. the High seas and the Area* (UICN, 2013). This agreement would affect the development of new industries by increasing the costs (additional administrative and reporting, technological and operational changes, etc), adding time and effort (planning, preparation, reporting, etc), developing new strategic considerations and new business and commercial opportunities (new partnerships and cooperation) (WOC, 2019).

In the context of the ongoing negotiations for a new BBNJ agreement, the Swedish Agency for Marine and Water Management has commissioned Anthesis to investigate possibilities for future exploitation of the sea in ABNJ within 30-50 years, focusing on new industries and human activities. The scope of the study was to outline the activities, technologies, and sectors that have the highest potential to be utilized in ABNJ within the defined timeframe and to discuss the findings in relation to BBNJ and possible strategic environmental assessment (SEA) requirements. The activities, technologies and sectors included in this study are the following: Research, human habitat (floating cities), carbon capture and storage (CCS), offshore energy (wind, solar, wave, ocean thermal energy (OTEC)), ocean plastic harvesting, marine genetic resources (MGR), marine biotechnology, and mariculture.

To forecast future development, each activity has been explored further to investigate the following areas : (1) The expected growth of the sector and probability of the activity in ABNJ; (2) The characteristics of the technology including the scale of developments; (3) The likely performers/developers. Furthermore, an analysis of the potential need for an SEA has been carried out. The aim was to find out in what way the SEA could be helpful in controlling the development of the ABNJ by making it more sustainable.

The results of the study include a probability and concession complexity matrix which shows how probable it is that the identified activities/industries will be developed in ABNJ within 30-50 years and the complexity of investment seeking concession in ABNJ. The aim of the matrix is to create a basis for an analysis on whether SEA is needed and/or recommended. Activities that have a high likelihood in being developed in the area, as well as having a high complexity, might experience the greatest value from an SEA. Those activities include Marine biotechnology, CCS, Multi-tech energy fields, but also human habitat

[1] IUCN. Covering areas beyond national jurisdiction.

and wind energy. However, the fact that SEA is currently applied mainly on governmental plans and programmes but most of the activities researched in this study are performed by private actors or public-private partnerships, highlights that the use of SEA and where it is required is a problem which needs to be addressed. It needs to be considered whether SEA is an obligation to be performed only by states and governments for major investments in ABNJ or also by corporations. In addition, it is important to consider and define even if (temporary) projects would require an SEA and what types of project need an SEA (e.g. how defined they are, how complicated the projects are, how long-term and how large they will be).

Another complicated dimension is the issue of who undertakes the SEA. Will it be a body or instrument established by the BBNJ instrument that is going to hold the process and approve an SEA or should it be done by the responsible state/s separately? If the activity is going to be performed in the middle of the ocean then who should be included in the public consultation process? Should those involved be states, representatives from other sectors or the civil society? In addition, what regulations will be applied and whose environmental target values will be taken as a base value?

List of acronyms

ABNJ	Areas Beyond National Jurisdiction
BBNJ	Biodiversity in Areas Beyond National Jurisdiction
CCS	Carbon Capture and Storage
EEZ	Exclusive Economic Zone
EIA	Environmental Impact Assessment
MGR	Marine Genetic Resources
OTEC	Ocean Thermal Energy Conversion
SEA	Strategic Environmental Assessment
UNCLOS	The United Nations Convention on the Law of the Sea

1 Background

Marine Areas Beyond National Jurisdiction (ABNJ) cover two types of areas:

- The High Seas
  The water column outside of EEZs (Exclusive Economic Zones). Normal EEZ boundaries are 200nm (370 km) from the coast. High Seas do not belong to any State's jurisdiction.
- The Area
  The seabed and ocean floor and subsoil thereof, beyond the limits of national jurisdiction.

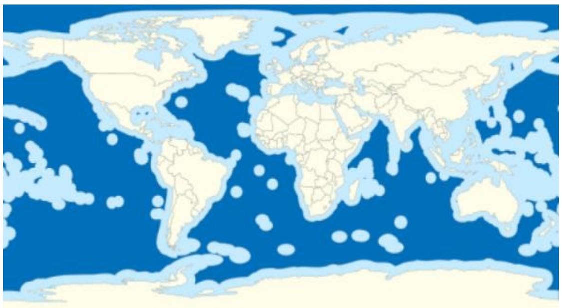

Figure 1 – Areas Beyond National Jurisdiction (dark blue) (IUNC)

ABNJ make up 40 percent of the surface of our planet and nearly two-thirds of the world's oceans. These areas are home to unique species and ecosystems that have evolved to survive extreme heat, cold, salinity, pressure and darkness. Furthermore, these areas can reach depths of over 10 km and represent 95% of the Earth's total habitat by volume.[2]

Humans have exploited the megafauna of the high seas for centuries and deep-sea fishing has taken its toll since the mid-1900's. Still, much of ABNJ ecosystems have remained relatively unaffected until recent decades. Today, technological advances have enabled fishing, fossil fuel extraction, deep sea mining and cable laying in areas that were previously logistically and economically inaccessible. Therefore, concerns about the sustainability of these activities and their effects on the vulnerable ecosystems in ABNJ have arisen.[3]

Today, the UN Convention on the Law of the Sea (UNCLOS) provides an international legal regime that governs the ocean. It creates an obligation to conserve the marine environment but does not provide specific mechanisms or processes for conserving marine biodiversity in ABNJ. However, countries are now negotiating a new global treaty in the form of an additional agreement to UNCLOS. This new treaty's aim is to ensure the long-term conservation and sustainable use of marine biological diversity in ABNJ through the effective implementation of relevant provisions of the UNCLOS and further international cooperation and coordination. This agreement is called the BBNJ Agreement (Biodiversity Beyond National Jurisdiction, BBNJ).

This agreement shall include requirements of Environmental Impact Assessments (EIA) for future activities seeking to operate in ABNJ. It may also include additional requirements for Strategic Environmental Assessments (SEA). This study addresses the relevance of such SEA requirements, considering which industrial sectors or technologies that may venture into the ABN.

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[2] IUCN. Covering areas beyond national jurisdiction.

[3] UNEP-WCMC (2017). Governance of areas beyond national jurisdiction for biodiversity conservation and sustainable use: Institutional arrangements and cross-sectoral cooperation in the Western Indian Ocean and the South East Pacific. Cambridge (UK): UN Environment World Conservation Monitoring Centre. 120 pp.

1.1 Strategic Environmental Assement

"Strategic Environmental Assessment (SEA) and Environmental Impact Assessment (EIA) effectively promote sustainable development by mainstreaming into economic development and integrating green economy targets into strategic and project-related decision-making," OECD (OECD, 2020).

The SEA is described in the Protocol on Strategic Environmental Assessment to the Convention on Environmental Impact Assessment in a Transboundary Context (SEA Protocol, Kyiv 2003). The Protocol was adopted by a Meeting of the Parties to the Espoo Convention, held on 21 May 2003 and entered into force on 11 July 2010. The Protocol on Strategic Environmental Assessment augments the Espoo Convention by ensuring that individual Parties integrate environmental assessment into their plans and programmes at the earliest stages, and thus help in laying down the groundwork for sustainable development.

SEA is a systematic and anticipatory process, undertaken to analyse the environmental effects of proposed plans, programmes and other strategic actions and to integrate the findings into decision-making. It is applied for example to government plans, programmes and policy documents. SEA originates from EIA with inputs from biophysical planning (applying methods of physics to the study of biological structures and processes) and policy analysis (Partidario, 2012). EIA is a tool designed to identify and predict the impact of a project on the bio-geophysical environment and on human health and well-being. Further it interprets and communicates information about the impact, analyses site and process alternatives and to provide solutions to sift out or abate/mitigate the negative consequences on humans and the environment. The tool is applied for example to power plants, motorways and energy parks (European Union).

The main difference between SEA and EIA is that SEA is applied on policies, plans and programmes whereas EIA is applied on projects. For example, in the European Union SEA is applied on public plans and programmes that include land use, transport planning, wide energy sector, waste management etc and which set the framework for future development. In addition, SEA is mainly applied in the public sector whereas EIA is applied in both the public and private sectors (*Figure 2*). SEA works by assessing physical, social and economic (and broad environmental) conditions for development while EIA directly assesses the environmental effects on policy, planning and programme proposals (Partidario, 2012). As Partidario writes in her report: "In practice what this means is that SEA should not be about the direct assessment of environmental effects of proposals (on water, air, soil, etc.) as in projects assessment, but instead it should be about the assessment of development conditions (institutional, policy, economic, social issues, etc.) towards the creation of better environmental and sustainability decision contexts and outcomes," (Partidario, 2012). The SEA process is started before a corresponding EIA is undertaken. This means that information on the environmental impact of a plan can cascade down through the tiers of decision making and can be used in an EIA at a later stage. This process should essentially reduce the total amount of effort.

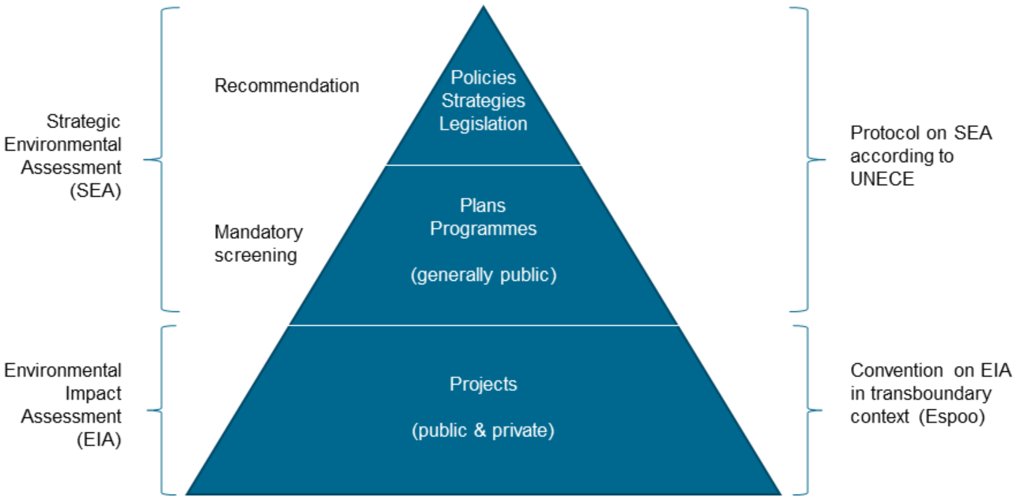

Figure 2 – Illustration of SEA in relation to EIA. SEA is an overarching process where an EIA is an important part for decision making and the adoption of plans or programmes that report on the environmental effects of plans / program proposals and alternatives.

SEA and EIA procedures ensure that the environmental implications are considered already in the decision-making process. The differences of these two can be seen in the table below.

Table 1 - Differences between SEA and EIA

	SEA	EIA
Methodology	**A political instrument** related to concepts	**A technical instrument** related to activities with geographic and technical specifications
Approach	**A proactive approach** – at earlier stages of the decision-making process to develop proposals	**A reactive approach** – at the end of the decision-making process – to a specific proposal
Process	**A multi-stage process** with variations e.g. policy vs plans	**Well-defined process**, clear beginning and end
Assessment	Assesses plans and programmes on a **macro scale**	Assesses projects on a more detailed level, on a **micro scale**
Scope	A larger range of activities in a **wider area**	Often a smaller range of activities on a **local scale**
Baseline	**Less details / qualitative**	**More details / quantitative**
Alternatives and cumulative effects	**Integrative,** gives early warning, considers a potentially wide range of development alternatives	**Specific** with limited review of cumulative effects, considers limited range of feasible alternatives (how to carry out projects)
Consultation	**Large range** of individuals and actors	**Smaller range** of individuals and actors
Emphasis	Emphasis on meeting **sustainability goals and safeguards**	Emphasis on **mitigation and minimising impact**
Focus	**Focus on 'do most good'** – i.e. explores the best development	**Focus on do no/least harm**

1.1.1 Why SEA?

SEA is a systematic decision support process, aiming to ensure that environmental and possibly other sustainability aspects are considered effectively in the elaboration of policies, plans and programmes. The process is structured, rigorous, participative, integrated, proactive and transparent, used by planning authorities, public and private bodies which can be applied to legislative proposals and other policies, plans and programmes in political decision-making.

Since SEA is undertaken early and often in advance of the formal decision-making process, it gives an opportunity to consider a wider range of alternatives and options at the planning and programme level. It influences the type and location of development that takes place in a sector or region, rather than just the design or siting of an individual project. Therefore, SEA facilitates sustainable development through addressing the consistency of plan and programme objectives with options from relevant strategies, policies and commitments.

Furthermore, SEA presents an opportunity to identify environmentally sustainable solutions higher up the decision chain before expensive planning stages of technical details. The process includes consultation and a public participation process. It also includes or prepares for a subsequent EIA and therefore strengthens the EIA and reduces investment risk.

The enhanced capability to address cumulative and large-scale environmental effects within the time and spatial boundaries of plans and programmes strengthens a project's EIA by "tiering" this process to the SEA report. This avoids questions (whether, where and what type of development should take place) which have been solved already with environmental consideration.

Partidario has identified four situations that may need an SEA: (1) The territorial area for action is known but the proposal's intentions are unknown or unclear; (2) The proposal's intentions are known but the territorial area is not identified; (3) Both the territorial area and proposal/intentions, are known; (4) The sectoral policy is known but does not have a territorial materialization (Partidario, 2012).

One example where an SEA could be used, is if an offshore wind energy development is proposed but the area for it is not identified yet. Another example of how SEA has been applied comes from Sweden where the Swedish Agency for Marine and Water Management has been commissioned by the government to develop sea plans for the Gulf of Bothnia, the Baltic Sea and the North Sea. AN SEA and associated EIA are made for each offshore plan. Swedish marine spatial planning includes a number of processes for analyzing and organizing activities in the water, on and above the surface, and on and at the seabed in such a way as to support the attainment of sustainable policy, social and environmental goals. The marine special plans shall provide guidance to the authorities and municipalities in planning and testing claims on the use of the area. These plans include Sweden's economic zone and the Swedish territorial sea from a nautical mile off the baseline. The municipalities have planning responsibilities for the part of the sea that is within the municipality's boundaries. This means that the municipalities and state planning responsibilities overlap in a zone of 11 nautical miles in the territorial sea.

Another example is from the European Union where SEA is mandatory for plans/programmes which are prepared for agriculture, forestry, fisheries, energy, industry, transport, waste/water management, telecommunications, tourism, town & country planning or land use and which set the framework for future development consent of projects listed in the EIA Directive. SEA is also mandatory for plans/programmes which are for plans/programmes which have been determined to require an assessment under the Habitats Directive.[4]

[4] EU. Strategic Environmental Assesssment – SEA. https://ec.europa.eu/environment/eia/sea-legalcontext.htm

2 Scope and method

Anthesis Sverige AB has been assigned by the Swedish Agency for Marine and Water Management to accomplish a qualitative desk study to support the understanding of technological trends for the industrialization of international waters (Areas Beyond National Jurisdiction) within the next 30-50 years, focusing on new industries and human activities. The scope of the study was to outline the activities, technologies, and sectors that have the highest potential to be utilized in ABNJ within the defined timeframe and to discuss the findings in relation to BBNJ and possible SEA requirements.

2.1 Method of the study

This qualitative desk study has been carried out in a form of Backcasting (*Figure 3*). It is a planning method that is increasingly used in urban planning and resource management of water and energy. It starts with defining a desirable future and then works backwards to identify policies and programmes that will connect this specified future to the present. The method involves establishing the description of a very definite and specific future situation. It then involves an imaginary movement backwards in time, step-by-step, from the future to the present to reveal the mechanism through which that specified future could be attained from the present.

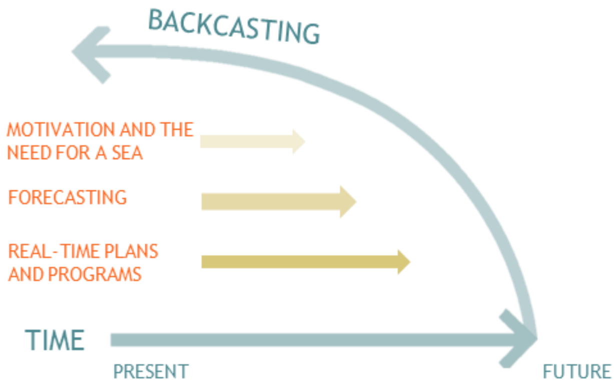

Figure 3 – Visualization of the Backcasting method and application to the study

The project has adapted the Backcasting method as followed:

1. Defining the "future" relying on trends
   In this step, factors and trends affecting the future development, including climate change, ocean plastic, rising sea levels, increasing global population and demand for food were analysed. The information was gathered from strategies and global programs that also created a base of understanding regarding how SEA and EIA could be applied amongst others to marine industries and marine planning. Among others, the following documents were considered in this step: (1) Analysis of Swedish marine cluster in Western Sweden[5]; (2) OECD reports including Ocean economy 2030[6]; (3) UNESCO report about global ocean science[7]; (4) Swedish national Marine Spatial Planning[8]; (5) Global Sustainability Goal 14 (Sea and Marine Resources), etc.

   The background study made it clear that there will be many societies and areas globally that will be affected by sea level rise and overpopulation. Therefore, there will be a growing concern about the location of settlements and the way in which people live in the future as well as about how the food supply would look like. Furthermore, knowing the increasing concerns regarding climate change pushes the energy sector to investigate more sustainable energy sources. This includes for example, researching the possibility of energy parks offshore. Where the wind is more stable, waves have a bigger potential for energy generation and there is no direct competition with habitats and the food sector on land. At the same time, with the knowledge that climate targets cannot be achieved if the

[5] Hansen, A.S., 2017. Omvärldsanalys 2017. Maritima klustret i Västsverige.

[6] OECD, 2016. The Ocean Economy in 2030. OECD.

[7] IOC, UNESCO, 2017. Global Ocean Science Report – The current status of ocean science around the world. UNESCO

[8] Currently under development

concentration of carbon dioxide is not lowered in the atmosphere, technologies that capture and store carbon dioxide underwater or underground are coming to the fore.

Increasing population growth and increasing income levels would result in higher consumption and therefore also in higher amounts of waste, including plastic waste. Already today over 300 million tons of plastic are produced every year of which at least 8 million tons end up in the ocean. Stricter regulations and rules, but also behavioural changes can decrease the amount of waste. However, technologies to collect the ocean plastic is needed already today to protect our sea environments. Another problem with increasing population is increasing demand for food and sustainable food supply.

To develop technologies and sectors in ABNJ, large scale research is needed. Research not only helps to investigate new ways to mitigate climate change, but also reveals the potential of other resources in the high seas that are currently unknown. This includes marine biotechnology (marine biomass and genetic resources) which are high on the research agenda and are relatively unexplored today in the high seas. These two areas are currently not widely developed but have a large potential for growth with greater research into ABNJs, especially research in the relatively unknown species living at the bottom of the ocean.

As a result of the first step, the following sectors that are believed to be developed in ABNJ within 30-50 years were identified: research, human habitat construction, carbon capture and storage (CCS), offshore energy, ocean plastic harvesting, marine biotechnology and food supply. The sustainability criteria have been a foundation for the assessment.

2. Forecasting the activities
   To forecast future development, each sector defined in step 1 has been further explored to identify possible areas of activities and technologies exploiting the ABNJ, including:
   - Marine research
   - Human habitats (floating cities)
   - Carbon capture and storage
   - Offshore energy (wind, solar, wave, ocean thermal energy conversion (OTEC))
   - Ocean plastic harvesting
   - Marine biotechnology
   - Marine genetic resources
   - Mariculture

   Those areas of activities and technologies were further investigated based on the following areas: (1) The expected growth of the sector and probability of the activity in ABNJ; (2) The characteristics of the technology including the scale of the developments; (3) The likely performers/developers. These areas for investigation were defined at the beginning of the project by the assignment owner, the Swedish Agency for Marine and Water Management. To investigate these areas, trends of each activity and technology have been considered together with investments costs and potential.

   The outcome of this step can be seen in the paragraph '*Description of considered activities in ABNJ* that is built in two parts: (1) Background information and trends of the activity; (2) Analysis of expected growth, scale of the development, and likely performers/developers and investors.

3. Motivation and/or need for an SEA based on the step 2
   Based on the results of step 2, an analysis of the potential need for an SEA has been carried out. The aim of this step was to find out what way the SEA could be helpful in controlling the development of the ABNJ. Today, there is no requirement to perform an SEA in ABNJ, however, if the exploration of these areas accelerates, it might be needed.

A probability and concession complexity matrix has been created based on the expected probability of activities, complexity of the concession and expected growth of the activity and/or technology. The validation of the need for an SEA and/or EIA is related to application of the concessions in the ABNJ. However, **major assessment uncertainty exists in the matrix and must be considered**. The matrix has been divided into four sections: (A) High probability in ABNJ and relatively low complexity; (B) High probability in ABNJ and high complexity; (C) Low probability in ABNJ and relatively low complexity; (D) Low probability in ABNJ and high complexity. Activities in sector B and D have the highest potential to benefit from SEA as they have a high complexity, often with a permanent infrastructure and/or permanent impact on the sea environment.

Scale of the y-axis: "Probability in ABNJ":

1. Very low, mainly coastal
2. Low
3. Medium
4. High
5. Very high probability, ABNJ presence already 2020

Scale of the x-axis: "Complexity of investment seeking concession in ABNJ":

1. Single units
2. Technically and spatially defined projects of several units
3. Spatially defined plans including multiple units (*i.e.* high technical flexibility within proposed area)
4. Larger development plans & programmes with high flexibility in geography as well as technology
5. Very large development plans & programmes with very high flexibility

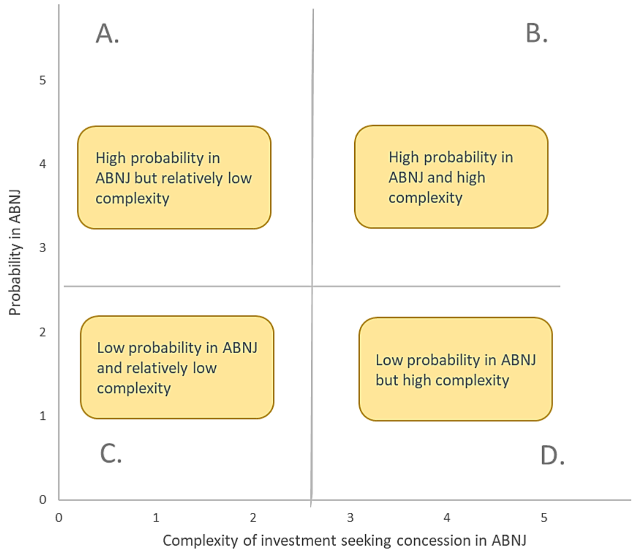

Figure 4 – Matrix: Probability of ABNJ investments vs. concession complexity. Major assessment uncertainty must be considered.

The outcome of this step can be seen in section 4.

2.1.1 Limitations of the study

This study focuses on relatively new activities/sectors in ABNJ and do not include shipping, fishing, oil/gas extraction and deep-sea mining because these sectors, with the exception of oil/gas extraction, are already covered by different international rules and regulations. It is important to be aware of considerable uncertainties in all assessment and analysis due to the investigative nature of the study. No scientific research has been carried out.

2.2 Vertical range of considered activities in ABNJ

The vertical operation range of considered activities in ABNJ is illustrated by *Figure 5*, approximately divided into surface water, pelagic zone, and/or ocean bottom.

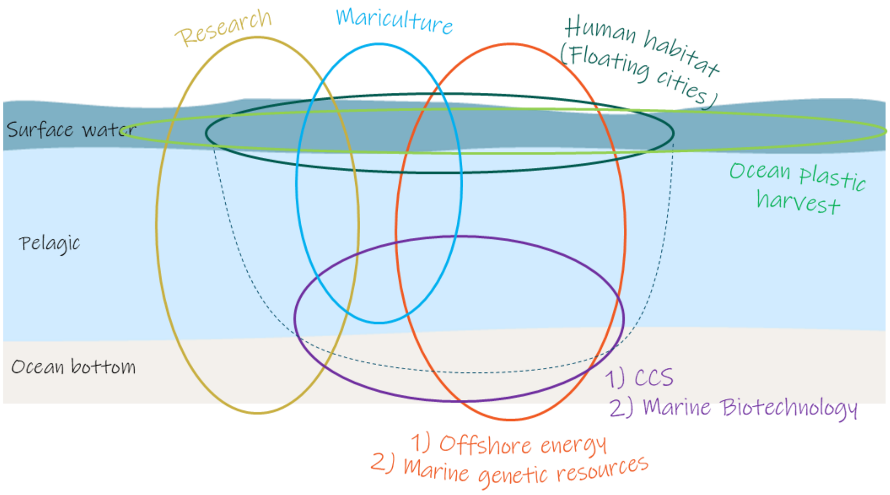

Figure 5 – Vertical range of considered activities in ABNJ.

Marine research: Activities taking place in the whole water column (surface water, pelagic zone and the ocean floor) are considered, for example, floating buoys, submarine drones and sampling of bottom fauna.

Human habitat (floating cities): In this study, human habitat activity has been narrowed down to just consider floating cities which are mainly located on the water but can also reach to the pelagic zone and the ocean bottom. The dashed line represents the possible environmental impacts of waste, harvesting and mooring, but also in some cases the infrastructure to fix the city.

Carbon capture and storage (CCS): Suitable places for storage of captured carbon dioxide are in the lower part of the pelagic zone and the ocean bottom. However, the exact location of the activity is highly dependent on future research.

Offshore energy: In this study, wind, solar, wave, and ocean thermal energy are considered. These energy sources can impact the whole water column and the ocean bottom, but this is dependent on its infrastructure. Today, most of these energy source infrastructures are fixed one way or another to the ocean floor but it is believed that when moving further away from the shore, more floating solutions need to be developed.

Ocean plastic harvesting: This activity occurs mainly in the surface water due to floating plastic waste.

Marine biotechnology: This activity consists of non-extractive exploitation of the biodiversity in all marine environments but mainly in the lower parts of the pelagic zone and the ocean bottom environments.

Marine genetic resources (MGR): Genetic resources can be found in every part of the water column, including the seabed.

Mariculture: This activity occurs mainly in the surface water and pelagic zone where target organisms can be cultivated. Infrastructure for mariculture consists mainly of floating equipment.

2.3 Financial challenges of exploiting ABNJ

Any venture in ABNJ will have very high investment costs that have an impact on the probability of the activity being developed. Uncertainty and risk often inhibit investors from far-offshore ventures. Some of the factors that are influencing investment costs are:

- Lack of existing infrastructure (Power cables, pipelines, building infrastructure, transportation)
- Rough physical conditions such as extreme weather, continuous wearing, and corrosion
- Long distances from the shore (High freight costs, high transmission losses, and high security risks)

Lessons learned from existing offshore industries show the tremendous importance of technical knowhow and offshore experience with great risk associated with moving too fast from controlled (laboratory) environments to upscaling to offshore implementation. However, large scale investments or synergies with other activities may reduce costs and risks and may therefore be necessary for profitable exploitation in ABNJ. An example of this could be developing multi-tech energy fields where the investments of developing infrastructure could be shared. Moreover, ventures in ABNJ are likely to be well prepared, politically as well as technically, and undertaken at a grander scale compared to nearshore activities.

3 Description of considered activities in ABNJ

The following section gives an overview of the activities included in the study, how they are performed, trends in their future development, and what future scenarios they may have.

3.1 Marine research

Marine research has a long history and is currently a growing field due to environmental concerns, such as climate change, and a revived focus on ocean resources. The Global Ocean Science Report considers the following categories as forming the field of ocean science: (1) Marine ecosystems functions and processes; (2) Ocean and climate; (3) Ocean health; (4) Human health and well-being; (5) Blue growth; (6) Ocean crust and marine geohazards; (7) Ocean technology. To cover these seven categories, the research methodology has been divided into three (Isensee, et al., 2017):

- Fisheries - marine fisheries, mariculture and aquaculture
- Observations – coastal and open ocean monitoring, data repositories, algal blooms, pollution, satellite measurements, buoys and mooring
- Marine research/other ocean science – such as experimental investigation and process studies.

Ocean research depends on novel infrastructure and technology from using sensors, research vessels and autonomous vehicles. Vessels provide access to both the open ocean and coastal areas. Advances in autonomous underwater vehicles and remotely operated vehicles have changed the overall infrastructure available for data collection. One example of this ocean research is the ARGO profiling floats programme coordinated by the Argo Project Office and the Argo Information Centre. This project allows the production of real-time maps and a range statistics on the status of the ocean. The network of about 4000 buoys includes drifting ice buoys, moored ocean sea floor buoys and buoys to measure atmospheric parameters. It is an excellent example on how to collaborate, share ocean science infrastructure and develop an extensive data management system (Isensee, et al., 2017). The typical cycle of an Argo float can be seen in *Figure 7*.

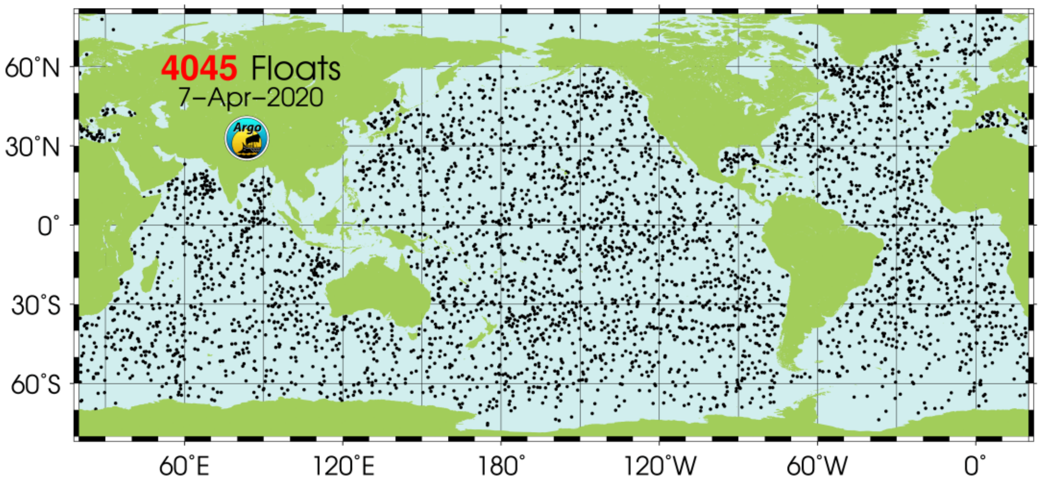

Figure 6 – The overview of Argo floats in the world[9]

[9] Argo. http://www.argo.ucsd.edu/

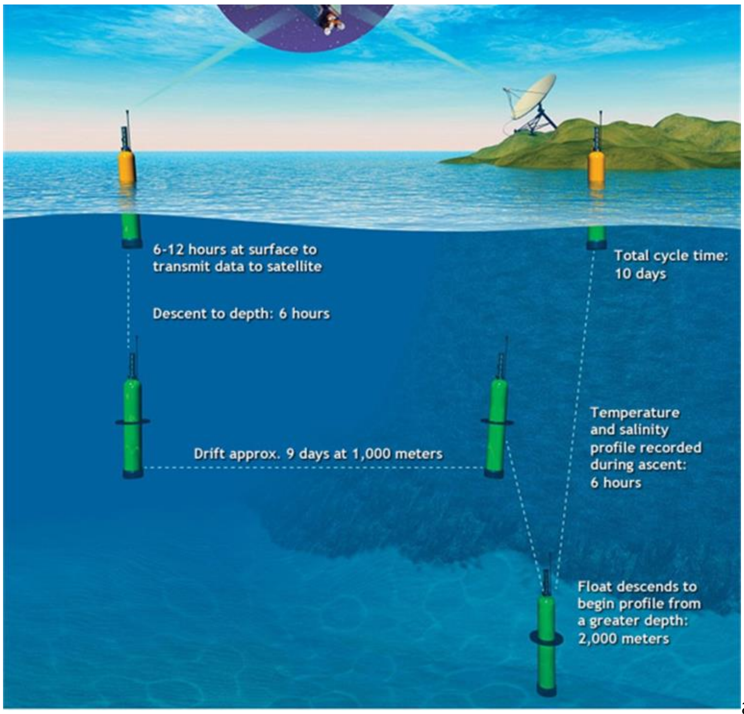

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Figure 7 - The typical cycle of an Argo float (Riser, et al., 2016)

Although the exact direction of future research may not be foreseeable, it appears that the trend towards using multiple automatic or remotely operated sampling vessels will characterize and greatly enhance future oceanographic, ecological, and geological scientific research. Ocean research will hence grow as a field with a high probability that it continues to be present in ABNJ. Most research units will be small, but efforts are likely to take the shape of larger sampling programmes (like the international Argo program). Investors range from single public and private operators to international co-investments. OECD sees national governments as the main funders of public research for the foreseeable future. However, the OECD also expects the private sector to increase their investments as they can be direct beneficiaries of the data for example, the oil and gas sector as well as offshore wind and aquaculture projects (Isensee, et al., 2017)

3.2 Human habitat (Floating cities)

Rapid population growth, urbanization, growing demand for food and biofuels, land degradation (Roeffen, et al., 2013) and climate change are causing high stress for coastal cities around the world. Studies estimate that by 2050, the additional land requirement for human activity is 13-36 million square kilometres. This number can be compared to, for example, the size of China (9.6 million km^2) and the total forested area globally (40 million km^2) (Roeffen, et al., 2013). Another example comes from Lagos where the lower income people need to live in floating villages on the outskirts of the town due to a lack of land and a growing population (UN, 2019). Blue 21 (2018) have developed a map to indicate the urban areas that have a high flood risk (**Error! Reference source not found.**). The results of their study show that most of the cities with a high risk are located in lowland areas in Asia (Blue21, 2018).

Figure 8 – Blue dots: rapidly growing cities with high flood risk; Orange: rapidly growing cities without high flood risk (Blue21, 2018).

To address some of the challenges that societies are experiencing today or will have in the future, many actors including the United Nations see floating cities as one opportunity. As seas and oceans account for 70% of the planet (361 million square kilometres), this space would be enough to accommodate the additional land requirements predicted to develop before 2050 (Roeffen, et al., 2013). Furthermore, floating cities have a large potential to be self-sustained in food and energy where people grow their own food and produce renewable energy (UN, 2019).

Most of the planned floating cities are close to existing cities where they would act as one part of the city. One of the biggest developers and designers of floating cities on the market today is Oceanix. In support of the UN-Habitat's New Urban Agenda, they have developed plans for a floating community for 10 000 residents on 75 hectares. This design, in line with the UN Sustainable Development Goals, channels flows of energy, water, food and waste, creating local sharing economies and self-sustaining societies. Another group of developers believes that building new societies in the middle of the ocean, in ABNJ, has other benefits - it gives an opportunity to experiment with new societies. One of these actors is the Seasteading Institute, founded in 2008 by Patri Friedman and Peter Thiel. They believe that floating cities allow the next generation of pioneers to test new ideas for living together (The Seasteading Institute, 2019). Currently, the Institute is working on a '*Floating City Project'* to develop their latest form of business which explores a model wherein a single company comprising several stakeholders will oversee construction and management of a highly autonomous floating city. The project is based on years of engineering and legal research (The Seasteading Institute, 2019). An example of a floating city can be seen in *Figure 9*.

Figure 9 – Concept designed by AT Design Office and CCCC, as one of the contributions in the architect design contest part of the Floating City Project (Wang, 2016).

Due to pressures such as population growth, urbanisation and climate change, cities will be under growing pressure. In this context, floating cities are seen as part of the solution. The sector would grow considerably in the future, but initially in coastal areas, as part of existing societies and urban areas, in warmer climates or closer to the equator. Roeffen et.al (2018) have identified in their study that cities in Asia would have the biggest effect and benefit from floating cities due to their high population rates. It can be supposed that there is a **moderate possibility that floating cities will be present in ABNJ** as the rough weather conditions of ABNJ are seen as a big challenge, alongside legal complications. Presence in ABNJ would provide the opportunity to develop new societies that are less dependent on existing ones. Most of such cities would require a **large development of plans and programmes** with **public-private partnerships**. For example, the Seasteaders believe in beyond the law communities with a political autonomy but also that there is still a need for cooperation with different countries and companies. Furthermore, floating cities provide good opportunity to develop other offshore activities, such as mariculture and marine energy.

3.3 Carbon capture and storage

Carbon capture and storage (CCS) is a technology that captures the carbon dioxide (CO_2) from the atmosphere or from industrial processes and stores it underground in depleted oil and gas fields or deep saline aquifer formations (Carbon Capture and Storage Association, n.d.). Increasing action regarding climate change would probably lead to a development of CCS technology as one of the tools to mitigate climate change by drastically reducing the carbon dioxide released or content in the atmosphere. However, it is difficult to predict which type of technology would be the most dominant in 2050.

CCS is also seen as one of the important opportunities to achieve large carbon dioxide emission reductions needed in the energy sector and to develop new energy sources, such as hydrogen. It is believed that CCS is one way to keep the costs of producing energy under control in the future when the taxes for carbon dioxide emissions would increase significantly (IEA, 2019).

At the end of 2018, there were only two large-scale CCS and utilisation power projects in operation, however, according to the International Energy Agency's Sustainable Development Scenario (SDS) the number of projects would increase significantly by 2040 (*Figure 10*). To achieve this goal, major innovations and cost reductions are required in the field. As the sector is only in the early stage of development, IEA believes that securing investments complimentary to targeted policy measures, such as tax credits or grant funding, are needed (IEA, 2019).

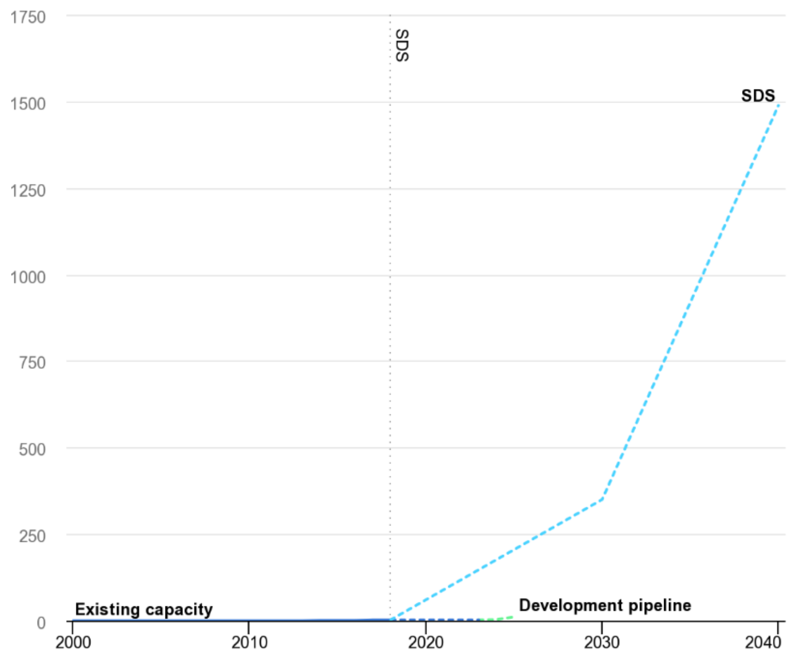

Figure 10 – Large-scale CO2 capture projects in power generation in the Sustainable Development Scenario (SDS), 2000-2040. Green line represents the development pipeline and dark blue existing capacity (IEA, 2019).

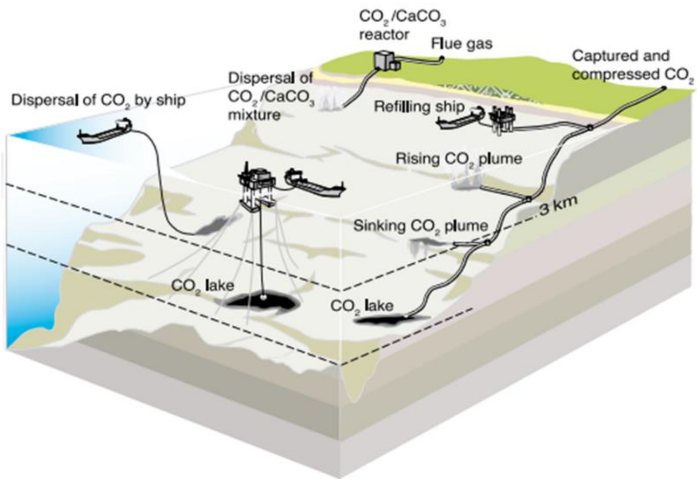

Figure 11 – Example of a CCS project (WMO & UNEP, 2005)

One example of a full-scale CCS project is the Northern Lights project taking place in Norway. The project includes capturing CO_2 from industrial sources in the Oslo-fjord region. The CO_2 is then shipped in a liquid form to an onshore terminal on the Norwegian coast. Next, the liquified CO_2 will be transported by pipeline to a permanent offshore storage location in the North Sea. Currently, one of the barriers in the project is that the CO_2 tax compared with the cost of implementing the CCS project is lower. Therefore, both subsidies and cooperation between government and industry are necessary to implement the project's ambitions (Lights, 2020). Another example of CCS infrastructure (not the Northern Lights project) can be seen in *Figure 11*.

The CCS sector will grow significantly in the coming years as it has a huge potential to help meet climate agreements while allowing to meet future energy demands. The probability of **the presence of CCS technology in ABNJ is high** as there could be many suitable areas (for example gas and oil fields) to store the carbon dioxide. However, the construction of sub-sediment ocean bottom structures is very expensive and will require large spatial surveys before technical specification can be completed. Most CCS projects would be **larger development plans and programmes** that would be carried out as **public-private partnerships or separately by private actors**. However, both private and public investments are required to get a strong market push. With public investment, we could see stronger carbon dioxide taxes, new policies and subsidies. The extent of the activity will vary depending on the technology and geological formations if aquifers are used.

3.4 Offshore energy

In this study, offshore energy includes wind, solar and wave power, and ocean thermal energy conversion (OTEC). Tidal energy and current energy are not considered as part of this study as suitable locations are associated with coastal features and are not present in ABNJ. Additionally, the technology is not assessed to be developed so far within the next 30-50 years.

Offshore energy technologies have developed making it possible to build arrays in deeper waters and further away from the shore. However, all developments are located within countries' territorial waters or EEZ. In 30-50 years, it is quite probable that developments extend into ABNJ. Incentives for this development would be the highest for countries with high energy demand and few land-based energy resources in combination with limited territorial waters and EEZ. For this development to be realized, the technologies need to be further developed in terms of (weather) robustness while the issues of energy storage and transport must be solved. Liquid hydrogen transported to port by ships may be an option and requires conversion plants installed at the offshore site.

Since transmission in the deep sea is difficult and expensive, energy storage can be a solution. One example to store energy from wind/solar/current or any renewable floating production site, is to store it as hydrogen. This concept was developed in the Netherlands and aims to convert produced power from offshore wind farms into hydrogen using electrolysis. The hydrogen can either be transported to land via ships or pipelines. An example of this designed concept can be seen in *Figure 12*. Another technology is to store the energy via a hydropneumatics liquid piston, driven by a reversible pump-turbine. This requires grid connection, but with storage in the piston technology, seasonal variations from offshore renewable energy production can be evened out and balanced.

Figure 12 – Designed concept for offshore platform developed by Tractebel (OffhoreEnergyToday, 2019).

3.4.1 Wind power

Wind energy has been dominant among the renewable energy sources during recent decades and is expected to remain as a key option for the coming decades. The market evolution has been remarkable, achieving several milestones, such as installations, technology achievements and cost reductions (IRENA, 2019). However, the real potential for this technology lies in offshore wind energy allowing countries to exploit stronger and sometimes smoother wind resources. Over the last decade the offshore wind sector has seen rapid technology improvements, supply chain efficiencies and logistical synergies (ibid.). Currently 90% of global offshore wind farms are in the North Sea, however, according to IRENA's report (2019), a prominent shift in the next three decades in offshore wind energy deployment will see development in Asian waters. Overall, the cumulated offshore wind energy capacity is expected to increase more than six-fold by 2030 (to 28 GW/year) and ten-fold by 2050 (to 45 GW/year) (*Figure 133*) (ibid.).

Furthermore, new technologies and floating foundations allow access to better wind resources further away from shore in deeper waters. Today, turbines are installed in water depths up to 40 meters and as far as 80 km from shore (*Figure 14*) whereas some projects are planned up to 200 km from the land *Figure 15*.

Similarly to other activities, investments play an import role in development. The global weighted average total installation cost for offshore wind projects is projected to drop from an average of 4353 US$/kW in 2018 to 1400-2800 US$/kW in 2050 (IRENA, 2019). At the same time, the annual average investment in offshore energy is expected to increase from 19.4 billion US$ to 100 UD$ in 2050. Major investments are required for new wind farms but also to replace existing and retired infrastructure with more advanced technologies. For example, wind turbines that are currently in a planning stage have a capacity of 10-20 MW/unit compared with the turbines that are already in place that have only a 2-6 MW capacity.

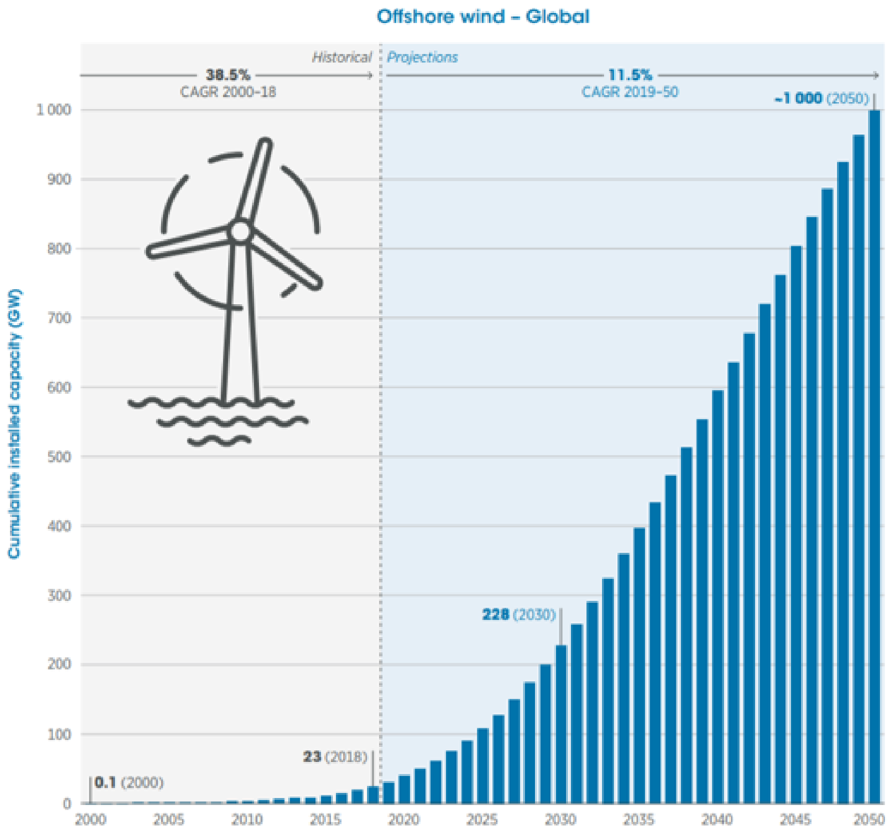

Figure 13 – Offshore wind power capacity until 2050 (IRENA, 2019).

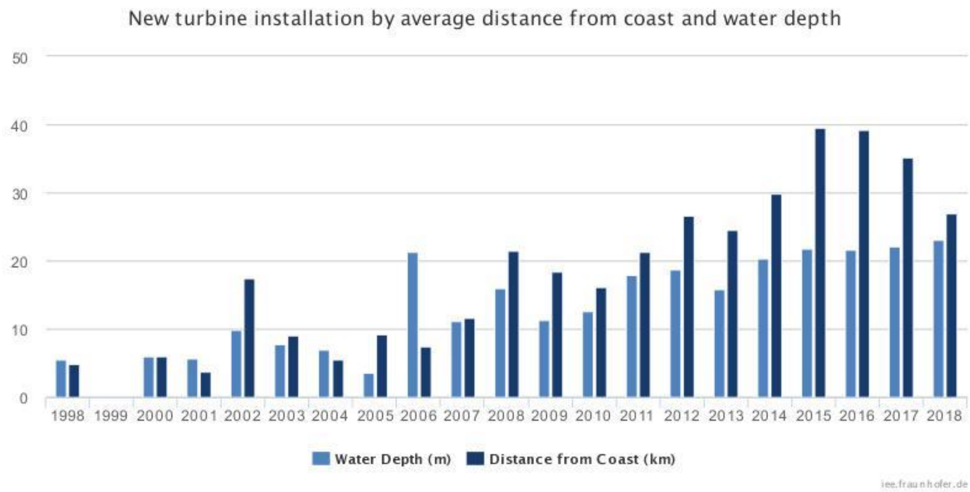

Figure 14 – New turbine installations by average distance from coast and water depth (Fraunhofer IEE, n.d.).

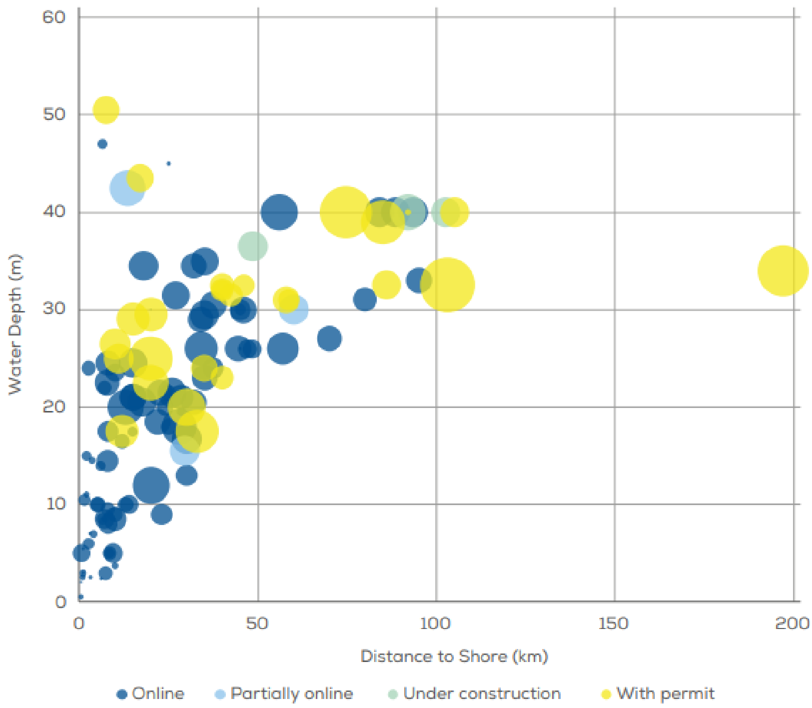

Figure 15 – Average water depth and distance to shore of bottom-fixed offshore farms, organized by development status. The size of the bubble indicates the overall capacity of the site (IRENA, 2019).

The wind energy sector is going to expand significantly in the future and has **a medium probability of being present in ABNJ**. We can already see a trend of building in deeper waters, further away from the shore. However, building wind farms far out to sea requires a different way of storing the energy produced than transporting it with cables. It is also important to consider the rough weather conditions in most areas of ABNJ which might make it challenging to build high infrastructure. Individual wind turbines are relatively small but whole farms would require **spatially defined plans with technical flexibility** and which would include multiple units. Investors in this field would be mainly **private but also governments** have a role to play in accepting new programmes and plans.

3.4.2 Solar power

Solar power means generating power through converting energy from the sun into thermal or electrical energy. The two main ways to produce solar power are: 1) Photovoltaics (PV) where the electronic devices convert the sunlight directly into electricity; 2) Concentrated solar power (CSP) where mirrors are used to concentrate solar rays to heat up fluid which creates steam to drive a turbine and generate electricity. PV is the most common technology installed on houses whereas CSP is used mainly in large-scale power plants (IRENA, 2020). It is expected that the total installation cost of a solar PV will decrease from 1210 US$/kW in 2018 to 481-165 US$/kW in 2050 (IRENA, 2019). Furthermore, IRENA is expecting that solar power together with wind power will lead the way in the transformation of the global electricity sector. IRENA predicts that the cumulative installed capacity of solar PV will rise to 8519 GW by 2050, becoming the second prominent energy source after wind by 2050 (ibid.).

Compared with solar power on land, the offshore solar power industry has been less developed. However, development has started during the last years where many countries and nations have started to invest, for example Japan, Singapore, Norway, Netherlands and France. One investment example is a Dutch company who is installing a solar energy park in the Dutch North Sea. The idea is to combine the same location with aquaculture and offshore wind power to use the available space more efficiently (DEME, 2019). The founders of the consortium (DEME, Tractebel, Jan De Nul Group, Soltech, Ghent

University) believe that factors such as land scarcity, large scale developments and the NIMBY (not in my backyard) mentality are supporting the offshore solar energy market as they have done with wind power. However, development is difficult due to salty water, strong currents and wave action. Nevertheless, the consortium has managed to build their first floating solar energy park which is now operational. In January 2020, they had 56 solar panels with a total capacity of 17 kW (Offshore Energy, 2020).

Offshore solar power has a **huge potential and the sector is only in the really early stages**. Together with wind power, it is believed that solar power will be one of the leading renewable energy sources for the future. Compared with building large solar energy parks on land, the offshore solar parks do not need to compete with human habitat and food production. However, it is still questionable today how far out from the coast the energy parks would reach in 30-50 years, and therefore **the probability of solar parks being present in ABNJ is rather low**. However, the occurrence of energy parks where solar and wind power are combined is more probable. To produce enough solar power for a plant to be cost-effective, large areas are needed with **spatially defined plans with technical flexibility**. Investors in this field would be mainly **private but also governments** have a role to play in accelerating energy independence and supporting green energy.

3.4.3 Wave power

Wave power means converting the energy of waves into electricity. There are two types of waves: 1) Wind seas (waves generated locally) and 2) Swells (waves generated by distant winds). The latter ones are especially interesting for the wave energy industry since the energy density is more consistent. Wave energy technologies vary from fixed structures to floating structures. Only 19% of structures are fixed and 67% are floating with the rest submerged (IRENA, 2014). The global wave power potential is approximately 29 000 TWh/yr, from which only a small part is currently extracted near coastlines, islands, and semi enclosed basins. However, development of the wave energy industry is also an increasing trend (Rusu & Onea, 2018).

The areas where the potential for wave power development is greatest, is on medium-high latitudes and in deep water (greater than 40 m deep) (IRENA, 2014), where the trade winds blow across large stretches of open ocean causing greater wave heights (*Figure 16*). In these areas, it is estimated that the power reaches to densities of 60-70kW/m (ibid.) At low latitudes, the energy content of surface waves are less, but oceanic swell may instead provide opportunities as a more constant and less violent energy source (Ocean Energy Systems & IEA Energy Technology Network, 2017).

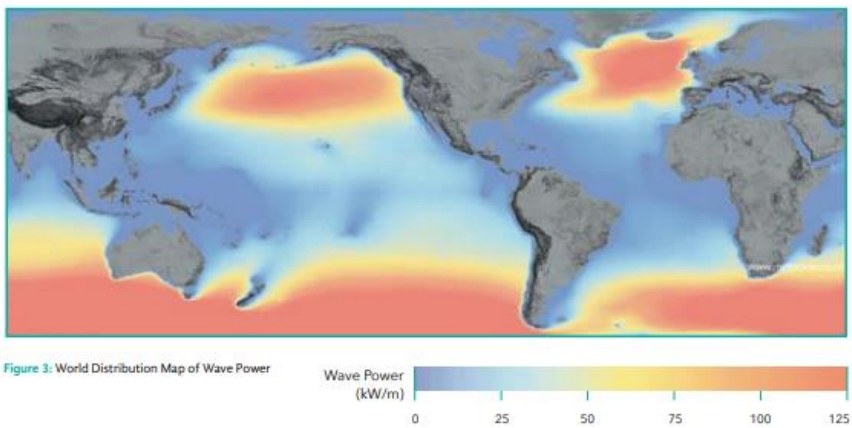

Figure 16 – World distribution map of wave power (Ocean Energy Systems & IEA Energy Technology Network, 2017).

Most wave energy converters needs to be designed to operate in a wide range of weather conditions. However, such weather-resistant and cost-effective wave energy installations are yet to be proven despite decades of development. Current devices, none of which are yet fully commercial, are relatively small units designed for coastal applications. Another issue is that small units have a high maintenance cost per energy output. Based on current experience, it is **unlikely that wave power will be cost effective in the context of ABNJ deployment**. Furthermore, extensive research and development is needed to assure cost reduction and efficiency. To achieve this, private and public partnerships are required where **private actors are seen as the main investors**. Even if today, most of the wave energy installations are single units, it is estimated that the future of wave energy lies in **synergies with other energy alternatives**, such as wind energy, to create bigger energy parks. This would help to reduce and share the costs and infrastructure.

3.4.4 Ocean thermal energy conversion

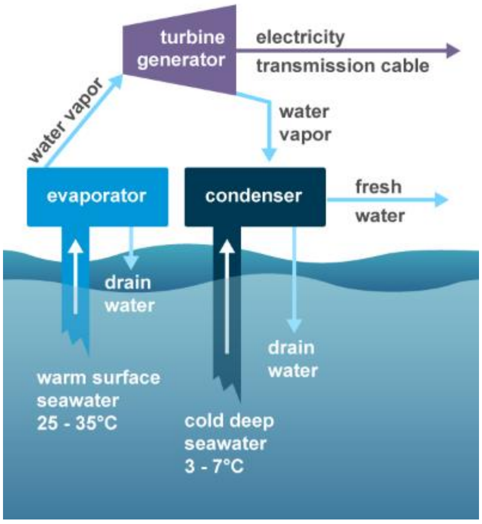

Figure 17 - Ocean thermal energy conversion system (EIA, 2019).

Ocean thermal energy conversion (OTEC) uses the temperature difference between warm surface water and cold deep seawater to generate electricity. Warm surface water is pumped through an evaporator containing a fluid that would vaporize and drive a turbine/generator. The vaporized fluid is turned back into a liquid in a condenser cooled with cold ocean water pumped from a greater depth. Depending on conversion principles, desalinated water may be collected as a by-product. The remaining seawater mix has to be discharged deep enough to keep nutrients from the deep sea apart from the nutrient poor surface waters in order not to trigger biological growth and eutrophication. The system is illustrated in *Figure 17***Error! Reference source not found.** (EIA, 2019).

The technology requires a permanent temperature difference of approximately 20 degrees which is possible only in near-Equatorial seas (*Figure 18*). The worldwide potential of ocean thermal power conversion has been estimated at 44,000 TWh/year (Ocean Energy Systems & IEA Energy Technology Network, 2017) which makes the technology attractive at scale. According to the International Renewable Energy Agency, ocean thermal energy conversion has the highest potential when compared with other ocean energy technologies as 98 nations and territories have viable OTEC resources in their EEZ (IRENA, 2014). Furthermore, OTEC has been seen to have a large potential for remote islands in tropical seas where it can be combined with other functions, such as air-conditioning and fresh water production (Kempener & Neumann, 2014).

Today, the main barriers associated with OTEC are high up-front capital costs and the lack of experience building OTEC large-scale plants (Kempener & Neumann, 2014). High costs are associated with piping, particularly for land-based solutions since the distance to deep water is far from the coast at most locations worldwide. Offshore solutions, where OTEC uses ocean heat gradient, have been suggested for decades due to their great potential but have not yet been tested at scale. Such solutions would require the transport of energy to land possibly by liquid hydrogen.

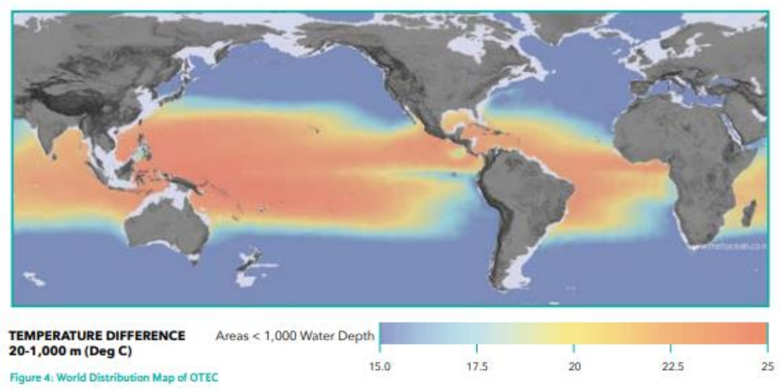

Figure 18 – World distribution map of OTEC (Ocean Energy Systems & IEA Energy Technology Network, 2017).

OTEC is believed to have the greatest potential in the ocean energy sector. There is a **moderate to high probability** that OTEC will be present in ABNJ. It may initially have to occur in EEZs close to the shore and only later move further to harvest the immense energy potential of tropical ABNJ. Each OTEC investment is likely to be a confined project, such as a moving barge with converted energy shipped to shore. In this context, OTEC are **single or multiple units** and project oriented which may not motivate SEA. On the other hand, environmental impact caused by vertical water exchange **motivates SEA** and cumulative impact assessments. Based on the immense energy potential across tropical oceans it is possible that multiple OTEC units will roam the equatorial seas harvesting the energy gradient. In such case, the spatial flexibility and range of OTEC may by itself be a strong motivation for SEA. Investors of OTEC range from **public and private operations to public-private partnerships**. On the other hand, a large-scale market increase requires big private investments.

3.4.5 Multi-tech energy fields

Multi-tech energy fields have a medium potential to be applied in ABNJ and might require spatially defined plans or larger development plans and programmes that includes multiple units. These fields have a great potential to use different types of energy sources in the same area while sharing the infrastructure and lowering the costs.

3.5 Ocean plastic harvesting

Over 300 million tons of plastic are produced every year of which at least 8 million tons end up in our oceans, making up 80% of all marine debris from surface waters to deep-sea sediments. This marine litter is a danger to marine species who ingest it or who are entangled in the litter, resulting in severe injuries and deaths. Moreover, plastic pollution also threatens food safety and quality, causing risks for human health. In addition, pollution can decrease coastal tourism (IUCN, 2018). Ocean plastic is caught in current swirls which cause big plastic “islands” in the middle of oceans. The biggest “island” lies in the northern part of the Pacific Ocean. Therefore, it is important and urgent to find legally binding international agreements to address marine plastic pollution (IUCN, 2018).

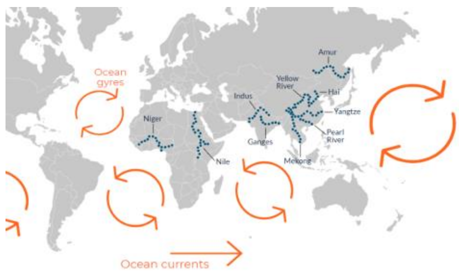

Figure 19 – Movement of river-borne plastic waste into the oceans (Simpson & Hitchen, 2019).

Researchers suggests that 5 countries (China, Vietnam, Philippines, Indonesia, Thailand) are responsible for 80% of the mis-managed plastic waste that enters the marine environment. Mismanaged plastic waste in 2010 can be seen in *Figure 20*.

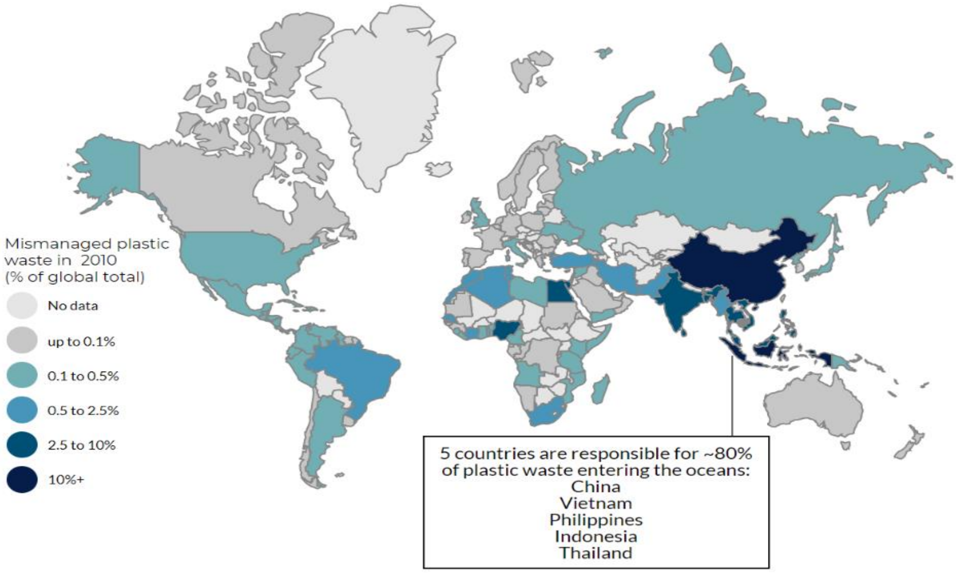

Figure 20 – Sources of ocean plastic waste (Anthesis, 2020, adapted from our world in data).

Ocean plastic has a direct financial impact on marine tourism (loss of revenue), governments (cleanup costs), and on fisheries and aquaculture (loss of revenue). The plastic can also have an indirect cost by causing problems for human health, impacting marine ecosystems and ecosystem services. Therefore, measuring the full economic cost of marine litter is complex. Moreover, due to its complexity and scale it is difficult for single actors to make a difference. Collaboration projects are needed to avoid new plastic flows into the oceans and to take drastic political decisions. However, already some researchers and private companies have started to harvest the plastic in the sea, especially in coastal territorial areas but also in ABNJ. There is a high probably that ocean plastic harvesting will increase in the future.

Figure 21 – The Interceptor, made by the company Ocean Cleanup, adapted to clean up plastics in rivers (The Ocean Cleanup, 2019).

One example is The Ocean Cleanup, a non-governmental organization, who managed to test their first automated debris collection technology in 2019. The organisation aims to collect up to 90% of all ocean plastic. However, due to the current low cost of raw plastic, it is difficult to sell ocean plastic as a high value product. One approach could be to market the ocean plastic as a niche product that companies would buy to produce luxury items. Technology like the Ocean clean-up technology will be developed and distributed further.

Due to increasing environmental awareness around marine litter and micro-plastic pollution, ocean plastic harvesting will increase in the future. Currently, many coastal territorial areas have already started collections with some actors also having reached out to ABNJ. Therefore, there is a **high probability** for ocean plastic harvesting to be present in ABNJ even in 30-50 years. The vessels and infrastructure to collect the plastic waste are temporary including **single units or technically defined projects** of several units. Therefore, the added **value of SEA would be low** as these activities already mitigates the negative impact on the sea environment. However, SEA can help to define the most sensitive and important areas to clean up and help to address if there would be permanent stations or platforms installed. Investors in ocean plastic harvesting technology range from **public and private organisations to NGOs**. If the technology scales-up and makes ocean plastic harvesting profitable, then more private actors would be interested in investing and therefore active in the field. These developments need to occur alongside policy change, such as increasing taxes on raw materials, and helping to create a marketplace for secondary plastic material.

3.6 Marine biotechnology

OECD defines marine biotechnology as follows: "The application of science and technology to living organisms from marine resources as well as parts, products and models thereof, to alter living or non-living materials for the production of knowledge, goods and services," (OECD, 2017).

Marine biotechnology applies to products extracted from marine organisms developed in laboratories using the knowledge of the natural processes in addition to marine organisms, or their parts. This field includes also creating products from marine DNA. The methods used in the field marine biotechnology vary from traditional forms, such as aquaculture, to modern bioprospecting (OECD, 2013). Resources from marine biotechnology are used in sectors such as energy (e.g. biofuels), pharmaceuticals (e.g. antibiotics), food (e.g. different fish species) and chemical industries (ibid.), and for other ecosystem services (e.g. biosensors and bioremediation). Further it helps to understand and map ecosystems based on generic biotechnological tools and knowledge (OECD, 2013). According to the OECD, marine biosources hold great potential to address the global challenges of food, energy security and health and to contribute to sustainable growth (ibid.). Many countries have seen this potential and are integrating this sector in their bioeconomy strategies. One example is the European Union which has identified it as an emerging sector with large potential for "blue economic growth". However, the sector also raises several challenges, including insufficient communication among stakeholders and the need for internationally coordinated action (ibid.).

The European Union believes that to be able to **accelerate the development of marine biotechnology in ABNJ**, environmental regulations, including the introduction of common licence systems, needs to be prioritized (Hurst, et al., 2017). The sector will **increase exponentially** in the future, but this is largely dependent on collaborative research and technological improvements. Today, the technical challenge is to access the areas outside of shallow coastal areas (ibid.). Moreover, the overall bioeconomy sector is advancing faster than ever before and is in high demand by consumers who are demanding sustainable solutions for food, fuel, sustainable products and health (ibid.). The infrastructure around marine biotechnology would be **spatially defined plans including several units.**

The investors in marine biotechnology range from the **private to public sectors**. It is believed that the potential growth of the sector lies in national and international cooperation. Furthermore, it is highly likely that in the future this sector will be highly regulated due to the shared and dynamic nature of ocean bioresources (OECD, 2013).

3.7 Marine genetic resources

Defining marine genetic resources (MGR) has been challenging and still needs to be set since it covers a broad range of organisms from micrometres to meters in lengths (Collins, 2019). However, according to the Convention on Biological Diversity (1992), genetic resources are genetic material (any material of plant, animal, microbial or other origin containing functional units of heredity (DNA)) of actual or potential values. MGR can be found in the whole water column down to the seafloor and below the seafloor (ibid). This area has great potential in the pharmaceutical, bioremediation, cosmetics, or biomedical innovation fields (EU, 2019). The applicability of MGR might even extend to the development of new food products.

During research carried out in 2018 (Blasiak, et al., 2018), scientists found that 47% of all marine DNA sequences were registered by a single corporation. Further, 98% of registered patents were located or had their headquarters only in 10 countries. Furthermore, universities and their commercialization partners had 12% of patents (ibid.). This data shows the large role of private companies in this field. In addition, most of the patents were registered in the last 15 years, including both the number of marine species used as a source for gene patents and the actual number of genetic sequences included in patent claims (ibid.).

Oldham et al. have developed a map to show the global occurrences of marine species in patent data over the past 10 years which can be seen in *Figure 22* (Oldham, et al., 2013) It is highly probable that most cases of access and use to these resources may not have been granted by national authorities when falling within the EEZ, thus probably leaving the patent applicant as the sole collector of benefits. This is confirmed by the fact that there are very few cases of ABS (Access and Benefit Sharing) contracts on marine resources and even fewer ABS laws specifically dealing with marine genetic resources. MGR patent occurrence records outside the EEZ and hydrothermal vents can be seen in *Figure 23*.

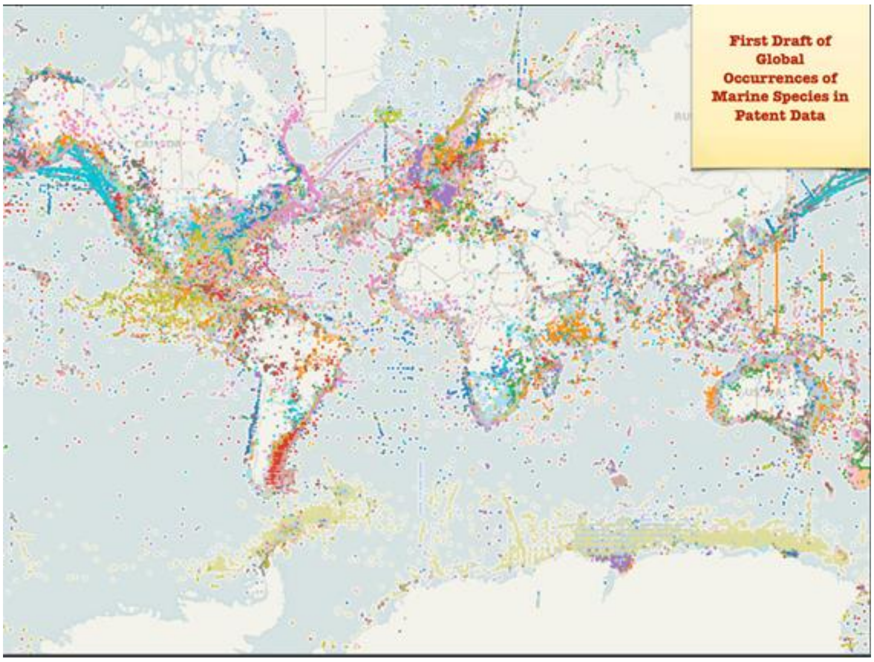

Figure 22. First draft of global occurrences of marine species in patent data (Oldham, et al., 2013).

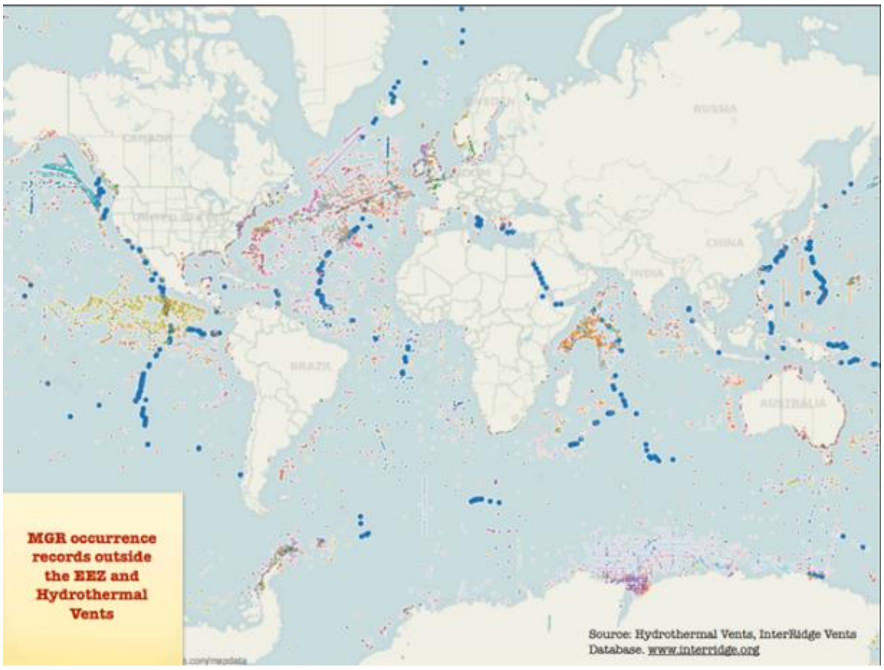

Figure 23. MGR occurrence records outside the EEZ and hydrothermal vents (Oldham, et al., 2013).

This sector **will grow significantly in the future** with research activity in **ABNJ**. However, MGR may be identified and to some extent harvested from the oceans but refined by laboratory facilities on land. Extraction volumes in ABNJ may thus be limited. Currently, MGR research is mainly lead by **private companies** to develop new products, with expeditions launched on **project level of complexity**. Regulation of marine genetic resources and benefit sharing related to them form part of the material being negotiated for the coming BBNJ-agreement.

3.8 Mariculture

Aquaculture has grown rapidly over the last three decades, increasing annually by 5.8% (2005-2014), accounting now for 44% of total global fish production. Increasing demand and consumption due to a growing global population are going to expand both inland and marine aquaculture further. Moreover, many coastal communities in tropical countries are highly dependent on fish as an important source of nutrients and income (Oyinlola, et al., 2018). Aquaculture involves both farming in fresh-water and farming marine organisms whereas mariculture is a branch of aquaculture which involves the farming of aquatic plants and animals in saltwater for example seaweeds, molluscs, crustaceans, and finfish (Water Encyclopedia, n.d.). In terms of marine animals, mariculture represents over one-third of fish aquaculture production and about a quarter of all marine fish production (FAO, 2018). Moreover, 97% of aquatic plant production is farmed today and 85% of a total production origin from China and Indonesia (Cisneros, et al., 2019)

Over half of the volume of the aquatic plants produced are seaweed (macroalgae). Seaweed is a relatively new food in western countries but has been consumed frequently in many Asian countries where operations are well-established. Seaweed can help solve food security issues but can also replace fossil fuels by the production of bioethanol and biomethane (bioenergy), and can help reduce ruminant methane emissions (Cisneros, et al., 2019). Further studies have shown that 48 million km^2 of the world's oceans in 132 countries is suitable for seaweed cultivation however currently, only 37 countries are currently cultivating it (ibid.)

Overall, studies (Oyinlola, et al., 2018) show that globally, oceans have unrealised potential for mariculture, especially offshore areas that are considered environmentally suitable (ibid.). Therefore, to find a suitable area to practise mariculture is not an environmental problem but socio-economic factors are limiting the expansion. These factors include political instability, technology (availability and cost effectiveness), trade, aqua feed availability, aquaculture policies and competition for space within an EEZ with shipping, oil, gas and tourism (ibid.). In *Figure 24* the potential of mariculture production can be seen (Oyinlola, et al., 2018) where the left map is a comparison of suitable and unsuitable areas for mariculture. On the right map, a comparison between the present number of species farmed in different countries with potential numbers of farmed species can be seen.

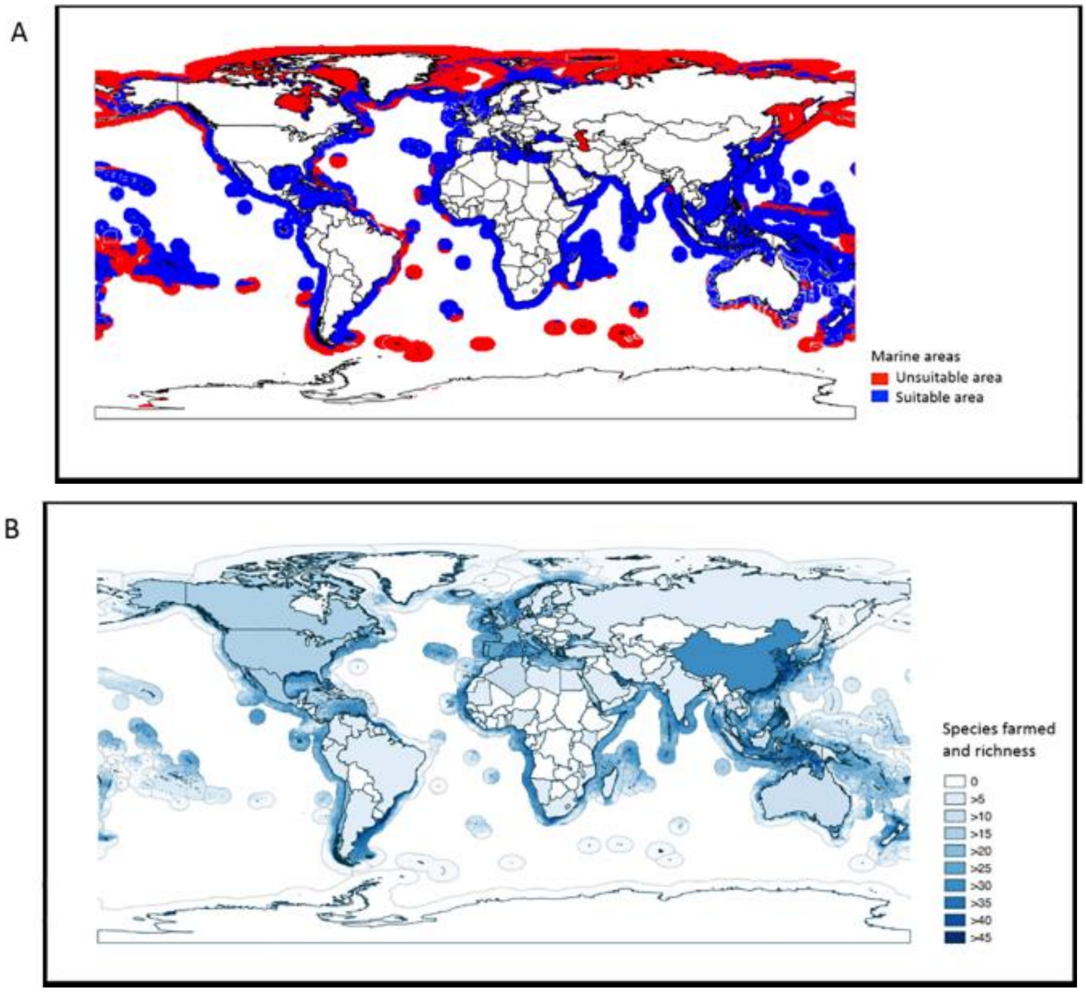

Figure 24 – The potential of mariculture production. (A) Blue: total predicted suitable marine areas for mariculture; Red: unsuitable marine areas for mariculture; (B) Comparison between present numbers of species farmed in different countries with potential numbers of farmed species (Oyinlola, et al., 2018).

One example of sustainable marine mariculture is integrated multi-trophic aquaculture (IMTA) where different fish and seafood species are living in symbiosis. This method has been practised for centuries in Asia, however, it appears to be a new concept in Western countries from the 1970s onward. IMTA mitigates the effects of nutrient enrichment from aquaculture systems by integrating different aquaculture species (e.g. fish or shrimp) with extractive organisms (e.g. shellfish, seaweed etc). By doing so, the latter species would take up the particulate and dissolved waste products from the fed organisms (*Figure 25*). This synergy would help sustain the health of coastal waters (Holdt & Edwards, 2014) but these systems are still uncommon on large commercial scale (Oyinlola, et al., 2018).

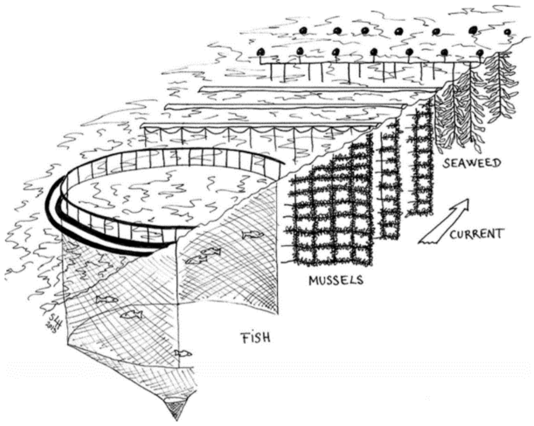

Figure 25 - Scheme of a multi-trophic aquaculture set up (Holdt & Edwards, 2014).

As mariculture has not reached its maximum potential, the sector **will grow significantly** in the coming decades. Today, mariculture is mainly practiced close to shores and in EEZs but according to the FAO it is only a matter of time before mariculture **will be present in ABNJ**. On the one hand, practicing mariculture in the high seas might create some important benefits, for example releasing pressure from the coastal environment (Percy, et al., 2013) and providing income for both developed and developing countries (Klinger & Nayloer, 2012). On the other hand, current mariculture practices highlight a range of problems such as regulatory caps, unsustainable production (Percy, et al., 2013), pollution, habitat destruction, disease risk to wild fish populations, and conflict with other public and private activities. Furthermore, offshore mariculture needs to be designed in a way to withstand challenging ocean conditions (ibid.). Complexity of the mariculture in ABNJ would be **technically and spatially defined projects of several units.**

Investors in this sector would predominantly be private. Mariculture has a potential to benefit consumers directly through increasing seafood availability but by also providing economic gains (Klinger & Nayloer, 2012). However, the long distance from shore would increase the costs of logistics, monitoring systems, remote feeding tools, vessels, fuel and labour (managing offshore vessels and equipment requires skilled employees). Therefore, it might be challenging for lower income actors to reach out to areas in the high seas. It has also been discussed that collaborating with other offshore operations, such as wind energy and decommissioned oil platforms, might help to reduce costs and capitalize on existing infrastructure (Klinger & Nayloer, 2012). It seems plausible to assume that mariculture in ABNJ, instead of coastal waters and EEZ, would first and foremost be relevant for sea food dependent countries with none or limited access to waters under its own jurisdiction, or for cultivation of species that need high seas conditions to thrive.

4 Results

In the following section, the results of the probability and concession complexity matrix is presented together with a discussion for the motivation and/or need for an SEA.

4.1 Probability and concession complexity matrix

Based on the expected probability of activities described in the previous section (y-axis), the complexity of the concession (x-axis) and expected growth of the activity/sector (size of the circle), a matrix has been made which focusing on the next 30-50 years. The aim of the matrix is to create a basis for an analysis on whether SEA is needed and/or recommended. However, **major assessment uncertainty exists and must be considered.** The matrix has been divided into four sectors: (A) High probability in ABNJ but relatively low complexity; (B) High probability in ABNJ and high complexity; (C) Low probability in ABNJ and relatively low complexity; (D) Low probability in ABNJ but high complexity.

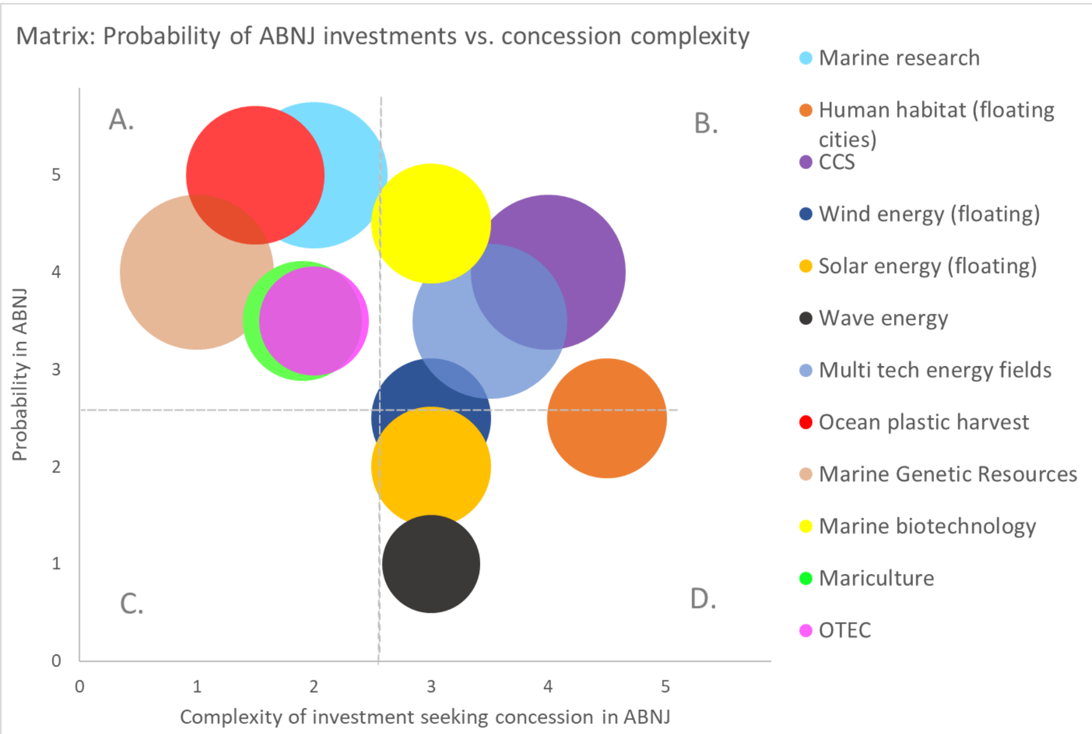

Figure 26 – Matrix: Probability of ABNJ investments vs concession complexity

<u>Sector A. High probability in ABNJ but relatively low complexity</u>

Activities that have a high probability to be developed in ABNJ but relatively low complexity are marine research, OTEC, ocean plastic harvesting, marine genetic resources, and mariculture.

Some of these activities are already taking place in ABNJ (marine research, ocean plastic harvesting, marine genetic resources) whereas the others (OTEC, mariculture) are likely to be launched there within the next 30-50 years. It is believed by the authors of the study that marine genetic resources and marine research will have the most extensive development in ABNJ in the next 30-50 years, followed by ocean plastic harvesting, mariculture and OTEC. The reason for this lies in the assessment that to be able to develop more activities in ABNJ, extensive research of the high seas needs to be done. Research might highlight economically beneficial areas and species with useful marine genetic resources that are still unknown today.

Activities in sector A have mainly single units and/or technically defined projects with several units. The exact complexity of those activities depends on the size of the project. For example, can research and ocean plastic collection projects be part of a larger program (e.g. Argo, The Ocean Cleanup) or be used for specific research in some short-specified time period. However, the overall trend seen in research and plastic harvesting operations is the utilisation of multiple automatic or remotely operated sampling/collection vessels. The motivation for this trend could be the high cost of technology and infrastructure needed to carry out the activity. With the same motivation, OTEC and mariculture have been assessed to have single or multiple units that are part of a larger project or development plan to reduce the cost of investment. Mariculture can be seen to have "fields" where there are many single units with personal and security devices. The layout of Marine Genetic Resources has been considered carefully due to high uncertainties of the resources available in ABNJ and how the sector would develop in the next 30-50 years.

<u>Sector B. High probability in ABNJ and high complexity</u>

This category includes the activities marine biotechnology, multi-tech energy fields and CCS. Activities like wind energy and human habitat are on the border line due to the moderate probability that they will be developed in ABNJ.

Most of these activities have no large-scale projects and/or programmes developed yet so far from the shore. However, it is believed that in the next 30-50 years it is likely that they will be present in ABNJ. This is however highly dependent on the technological development of energy sources and the discovery of suitable areas for CCS further away from the shore. If such areas are found, then the activity will probably expand significantly. Wind energy infrastructure may be fragile in open seas with big storms and high waves, requiring expensive maintenance. However, the offshore wind resource is more stable compared to land. Today, wind farms are built 30 km offshore and planned up to 200 km, due to floating mooring techniques.

Human habitats (floating cities) have a moderate probability of occurring in ABNJ because current development plans are for the cities to mainly occur close to existing cities in coastal waters. However, there are also some ideas where the aim of a floating city is to be independent from other societies and nations which makes the ABNJ appropriate as an area for development. However, development in the ABNJ can be limited due to political challenges as well as rough weather conditions.

Activities placed in sector B have a high complexity and are mainly spatially defined plans including multiple units (marine biotechnology and wind energy), larger development plans and programmes (CCS), or very large development plans and programmes (floating cities). Multi-tech energy fields are somewhat in between 3 and 4 on the scale because they are highly dependent on the energy source used and the size of the investment. Multi-tech energy fields have a great potential to use different types of energy sources in the same area while sharing the infrastructure and lowering the costs. Compared with multi-tech energy fields, wind energy farms have been assessed to have a lower complexity since the technology is more uniformed than investing in several different types of energy sources. CCS would require vast seabed space and therefore would take shape through larger development plans and programmes.

<u>Sector C. Low probability in ABNJ and relatively low complexity</u>

No activities that were included in this study were placed in this sector because most of them either have a high potential to be developed in ABNJ and low complexity or high complexity and a low probability to be developed in ABNJ. This was part of the selection phase and criteria for further investigations.

<u>Sector D. Low probability in ABNJ but high complexity of the project</u>

Activities included in this sector are wave energy and solar energy. These two energy sources may take longer than 30-50 years before being developed in ABNJ. Even if the wave potential is large in the high seas, it is unlikely that development in ABNJ will be cost effective in the near future. The development of this technology is believed to create bigger technological challenges compared with wind and sun energy technology. However, both activities can be part of the multi-energy parks where the investments costs are shared between different energy sources. Furthermore, wave energy technology is very weather resistant which makes it suitable for storms and rough conditions. Solar energy is believed to be used initially on land, ships, floating cities, platforms and integrated with other activities.

Both activities in sector D are considered to be elaborated and presented as spatially defined plans with technical flexibility, allowing step-wise planning to maximize cost-efficiency in such risk prone venture.

4.2 Motivation and/or need for an SEA

Activities placed in sector B on the matrix (*Figure 26*) would experience a moderate to high value addition from an SEA. Those activities (marine biotechnology, CCS, multi-tech energy fields, but also human habitat and wind energy) include spatially defined plans including multiple units until very large development plans and programmes. Most of those activities would have a long term to permanent impact on the sea environment. For example, storing carbon in the lower parts of the ocean and in the seafloor would make the area mostly unavailable for other activities. Following this, it would be highly beneficial to choose the most suitable technology for different areas in ABNJ. SEA requirements would be particularly helpful in optimising spatial design and addressing conflicts of interests. Conflicts of interest would occur when building large-scale multi-tech energy fields that would cover larger areas of the sea and might affect other activities, for example shipping.

A key question is to address who owns the resources in the sea. With marine biotechnology, SEA has a strong advantage for protecting certain sensitive species across space and over time, which may not be possible with occasional EIA procedures. The SEA could help in keeping within the legal regime that governs the exploitation and benefit sharing of the oceans. Finally, applying SEA to human habitat (floating cities) would be of high value because of its macroscale and complex approach of the activity. The open and transparent process of SEA as well as the fact that SEA takes into account environmental and sustainable aspects for decision making are import factors for its use.

Activities placed in sector B (marine research, ocean plastic harvesting, marine genetic resources, mariculture, OTEC) on the matrix (*Figure 26*) would experience a low to moderate value addition from an SEA. These activities have single to multiple units that are mostly temporary covering smaller areas. For example, even if there is currently a lack of significant regulation on the mariculture sector in the high seas, an EIA might be enough since the activity would be project based and have a low complexity. An EIA would help to mitigate environmental problems connected with mariculture occurring already (e.g. over fertilization, invasive species, etc). SEA would even have just a little impact on ocean plastic harvesting since the vessels and infrastructure used would be temporary and would have a mitigative impact on sea pollution. However, a strong EIA might be needed for example to regulate dimensions and technologies, to identify the most sensitive and important areas to clean up and to conduct a cost/benefit analysis on the specific clean-up methodology.

Activities in sector D (Solar power, wave power) on the matrix (*Figure 26*) are assessed to have relatively low to moderate value addition from an SEA. These activities have the smallest probability of being developed in the ABNJ. If they were to be developed in the high seas, an SEA might be helpful to handle cumulative effects and conflicts of interest. However, it is believed that currently a strong EIA would be also enough.

The fact that SEA is currently applied mainly on governmental plans and programmes but most of the activities researched in this study are performed by private actors or public-private partnerships (except the activities in the B sector) highlights that the use of SEA and where it is required is a problem which needs to be addressed.. It needs to be addressed whether SEA is obligated to be performed only by states and governments for major investments in ABNJ or also by corporations. In addition, it is important to consider and define even if (temporary) projects would require an SEA and what types of project need an SEA (e.g. how defined they are, how complicated the projects are, how long-term and how large they will be). Difficulties of those “grey” areas can be seen already where for example shipping is considered as a project in ABNJ even though shipping should be part of sea planning and should require SEA according to EU regulations. Another example is deep sea mining in ABNJ where states apply for extraction rights and companies implement their projects through states.

Another complicated dimension is the issue of who undertakes the SEA. Will it be a body or instrument established by the BBNJ agreement that is going to hold the process and approve an SEA or should it be done by the responsible state/s separately? If the activity is going to be performed in the middle of the ocean then who should be included in the public consultation process? Should those involved be states, representatives from other sectors or the civil society? In addition, what regulations will be applied and whose environmental target values will be taken as a base value?

5 Conclusion

In light of the ongoing negotiations for a new implementing BBNJ Agreement, the Swedish Agency for Marine and Water Management commissioned Anthesis to investigate possibilities for future exploitation of the sea in ABNJ within 30-50 years, focusing on new industries and human activities. The scope of the study was to outline the activities, technologies, and sectors that have the highest potential to be utilized in ABNJ within the defined timeframe and to discuss the findings in relation to BBNJ and possible strategic environmental assessment (SEA) requirements. The activities, technologies and sectors included in this study are the following: research, human habitat (floating cities), carbon capture and storage (CCS), offshore energy (wind, solar, wave, ocean thermal energy (OTEC)), ocean plastic harvesting, marine genetic resources (MGR), marine biotechnology, and mariculture.

Looking at ocean economics globally, many offshore industries can outdo the growth of the world economy as a whole. Future scenarios show that the ocean economy, under a 'business as usual' scenario, will double its contribution to the Gross Value Added and amount over US $ 3 trillion regarding 2010 to 2030. Growth is particularly expected in the mariculture, offshore wind and fish processing industries as well as in shipbuilding and repairs. Offshore industries will also increase employment growth, where it is expected (under BAU[10]) to have 40 million fulltime employees by 2030 within the sector. This increase comes from offshore wind power, mariculture, fish processing and port activity (OECD, 2016).

Trade in the marine sectors can be boosted by introducing sound regulatory and institutional frameworks to develop ancillary services needed to undertake these activities, including financial, insurance, communications, testing, certification and research and development (R&D) activities. In addition, the way in which resources are harvested and processed matters increasingly to consumers globally. In this regard, trade can be an enabling factor in the promotion of sustainable activities, moving the production of ecologically 'friendly' goods from niche market segments to mainstream international trade, thus responding to evolving consumer demand (Eugui, et al., 2014).

The coming decades will also include scientific and technological progress which can produce significant improvements in many of the sea related environmental challenges and aid the development of offshore economic activities. The offshore industries will grow at such a rate that there will be a huge risk that the stress on the already stressed natural resources in the ocean will increase. Here, regional and national strategies and frameworks will play an important role in improving the governance and marine management to reduce that risk (OECD, 2016).

To forecast future development, each activity has been explored further to investigate the following areas : (1) The expected growth of the sector and probability of the activity in ABNJ; (2) The characteristics of the technology including the scale of the developments; (3) The likely performers/developers. Furthermore, an analysis of the potential need for an SEA has been carried out. The aim was to find out in what way an SEA could be helpful in controlling the development of the ABNJ by making it more sustainable.

Based on the results of the study, the activities covered can be divided into two categories: (1) Activities that would experience a high value addition from an SEA; (2) Activities that would experience a medium to low value addition from an SEA.

Activities/industries that belong to the first group include marine biotechnology, CCS, multi-tech energy fields, but also human habitat and wind power. These activities have a higher complexity and a higher likelihood to be developed in ABNJ. Due to this, they may create bigger conflicts of interest and a more permanent impact on the marine environment, but the flexibility also opens up for more adaptation, holistic planning, and environmental mitigation.

[10] Business As Usual

SEA may have less immediate value to the rest of the activities/industries: marine research, ocean plastic harvesting, MGR, mariculture, OTEC, wave energy and solar energy. OTEC is the technology that would have the most added value in this group from an SEA, i.e. a medium value addition due to its environmental concerns. The first two activities have mitigative effects on the sea environment and have single or multiple temporary infrastructure that would not cause long-term negative effects. The other activities in these categories (A, C and D) would need strong EIA requirements in order to regulate dimensions and technologies used, for example.

It should be noted that this reasoning is kept on a generic level, the value of SEA for each of these activities/industries may differ on a case-by-case basis, addressing the required area, conflicts of interest and the complexity of the project. As ABNJ are not as regulated as EEZs, it is important to ensure the sharing of the resources of the ABNJ and area in a way that everyone can benefit fairly from it, preventing monopolisation from big corporations and richer countries who have the means for investment.

The fact that SEA is today applied in governmental plans and programmes but most of the activities researched in this study are performed by private actors or public-private partnerships (except the activities in the first group), highlights that the use of SEA and where it is required is a problem which needs to be addressed. It needs to be addressed whether SEA is obligated to be performed only by states and governments for major investments in ABNJ or also by corporations. In addition, it is important to consider and define even if (temporary) projects would require an SEA and what types of project need an SEA (e.g. how defined they are, how complicated the projects are, how long-term and how large they will be). Difficulties of those “grey” areas can be seen already where for example shipping is considered as a project in ABNJ even though shipping should be part of sea planning and should require SEA according to EU regulations. Another example is deep sea mining in ABNJ where states apply for extraction rights and companies implement their projects through states.

Another complicated dimension is the issue of who undertakes the SEA. Will it be a body or instrument established by the BBNJ instrument that is going to hold the process and approve an SEA or should it be done by the responsible state/s separately? If the activity is going to be performed in the middle of the ocean, then who should be included in the public consultation process? Should those involved be states, representatives from other sectors or the civil society? In addition, what regulations will be applied and whose environmental target values will be taken as a base value? These are questions equally valid for the foreseen EIA processes in ABNJ and a matter debated in the ongoing treaty negotiations.

To conclude, based on this study, Anthesis believes that several future activities in ABNJ will strongly benefit from SEA requirements, both from an environmental perspective and for the developers. However, all aspects need to be thought through to optimise the benefits of each branch of activities. Anthesis recommends considering setting up working groups for each sector to manage future activities and their impact on marine biodiversity.

Anthesis

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Anthesis is the sustainability activator. We seek to make a significant contribution to a world which is more resilient and productive. We do this by working with cities, companies, and other organisations to drive sustainable performance. We develop financially driven sustainability strategies, underpinned by technical expertise and delivered by innovative collaborative teams across the world.

Our Swedish business reinforces Anthesis' sustainability diagnostics services in the field of environmental economics, sustainability analysis and energy efficient and sustainable cities. In these areas we offer strategic advice as well as business development, analysis and investigation, evaluation and research and education. Our employees in sustainable energy are among the country's foremost experts and our employees in environmental economics have a solid competence in various types of socio-economic analysis. With a firm background in urban development, and by using a diverse tool box of quantitative and qualitative methods, the team provide a solid link between theory and sustainable practice.

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