

# An Ocean Full of Opportunities

Visions of the Future of the Ocean

Stéphanie IJff and Marie-Pauline van Voorst tot Voorst  
Netherlands Study Centre for Technology Trends (STT)



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## Colophon

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Stéphanie Ijff  
Marie-Pauline van Voorst tot Voorst  
(ed.)

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STT, 2016



### **Hans Huis in 't Veld, Chairman Top Sector Water**

Whenever I sail the seas with my sailing boat I become intensely aware of the the vastness and beauty of the water. On the water I enjoy myself to the full. The sea and the ocean mean much to me, here I find peace.

Lakes, seas and oceans have always been of invaluable to mankind. For centuries they have been supplying us with food and drinking water and we use them for trade. We continuously find new ways to use water, for instance the possibility to extract renewable energy from the ocean. In the upcoming decades the growth of the population and prosperity will increase the global demand for food, raw materials and energy. We use the natural waters more and more intensive: large fleets catch an increasing amounts of fish, deep sea robots can extract raw materials from the bottom of the ocean, and a growing number of offshore platforms.

The ocean is vast, but not inexhaustible. During my sailing trips I regularly come across pollution in the shape of floating plastic. But there are also invisible forms of pollution and damage to the ecosystem. The damage poses an enormous challenge: how can we make use of the ocean to promote our well-being and prosperity and still preserve it for future generations?

We should not see this question as a threat, but rather as an opportunity for the Netherlands, Europe and the world. As the chairman of the Top Sector Water I witness the innovative power of the water sector on a daily basis, including maritime technology. But there are also other sectors – such as fishing, agriculture, energy and oceanographic research – where

we see institutes and businesses taking a leading role on the international stage, while using the latest technologies. In using the ocean for our well-being and prosperity, we should especially apply sustainable technologies in, while ensuring that this blue, fascinating world stays healthy.

Apart from technology we should not underestimate the Dutch expertise in governance. The ancient roots of the so-called polder model and the recent experience with highly complex area processes – such as the Room for Rivers programme – have generated much experience in bringing different sectors together and taking the uncertain future into account when drawing up policy and area plans. We can use this knowledge in the international debate to reach global agreements on how we intend to treat the ocean. This is very necessary since much is to be done yet.

The Netherlands has much to offer, but this will require us to join forces. That is why I am very happy with this STT publication. A vast network of research institutes, ministries, non-governmental organisations and businesses has come together to discuss the question: how can we make sustainable use of the ocean in 2050 to promote global well-being and prosperity? The result of this discussion you are looking at.

The visions of the future in this book are meant to stimulate reflection. How can we combine technology and the sustainable use of the ocean when it comes to food, raw materials and energy? Will the ocean be able to contribute to dealing with the effects of climate change? Which international agreements are required to keep the oceans healthy? What will the consequences be of living on the ocean?

It is my sincere hope that this book is not the final stage of an interesting survey, but rather the starting point of a broad, national and international debate. The only way to move forward is to enter the debate with each other and to come to agreements. If that happens I have no doubt we will be looking at an ocean of opportunities.





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What will be the role of the ocean in 2050? Will it be an uninhabitable, overfished and – if we look at resources such as oil and rare materials – a completely exhausted underwater world continuously fought over by nations? Or will the ocean have become our ally, helping us to feed the global population of (by then) 9 billion people, rendering all kinds of services without ever being exhausted? An ally that will help us deal with the effects of climate change? This book offers ideas on the possible future of the ocean and what we can do to achieve this. Choices we make today may have a large impact on the future. If we do not act now we may create problems that can possibly not be solved by future generations. There is still time left, though. Visions and ideas on the sustainable use of the ocean are already in existence. New technology creates an increasing number of opportunities. It is time to join forces on a global scale. The ocean covers 71 percent of the surface of the earth. 70 percent of the global oxygen production comes from algae at the ocean surface. The ocean provides food and raw materials and enables transport around the globe. It also has a large impact on the global natural systems. What will things be like in 2050? The main question of the STT futures study *An Ocean Full of Opportunities* was: how can the ocean in 2050 contribute to the supply of natural resources and the dealing with the effects of climate change, provided that the ocean is preserved and used in a sustainable way?

The focus of this book is on technology and governance.

The ocean is the driving force behind large and important systems such as the climate, the water cycle and the carbon cycle. No less than 3 billion people rely on the ocean for their daily subsistence. This implies that we are facing threats like overfishing, the dumping of waste, disturbance of marine ecosystems as the result of exploitation, etc. The ocean acts as a buffer for heat and CO<sub>2</sub>, but the warming of the surface water (0.7°C in the past 100 years) already has an impact on specific fish species. Overexploitation and heating are two of the main threats to the ocean, followed by biodegradation, acidification and pollution.

Developments in e.g. sensor and information technology and robotics enable new commercial activities, which in turn increasingly threaten unspoilt environments. But these technologies can also help us gain a better understanding of the marine ecosystem. For instance, sensors can help to identify specific fish species and thus minimize by-catch. Other technologies and materials are equally promising, such as robotics (already used for laying pipelines at the bottom of the ocean) and biotechnology (production of medicine and enzymes by marine organisms). The top 5 of technologies that will play a major role in the exploration, exploitation and monitoring of the ocean in 2050 is, according to experts, made up of robotics, sensor technology, IT, deep sea mining technology and transport technology.

How can the ocean contribute to the supply of natural resources and the dealing with climate change in 2050, and still be preserved and used in a sustainable way? The workshops in this futures study led to various solutions. Some of these are already being developed, others are still a long way off. The increasing global population requires a growing amount of food. The ocean can supply algae and seaweeds, for example. Ocean farms will soon render trawler fishing obsolete. These farms work with a (nearly) closed cycle.

The ocean is rich in raw materials that are often found in unstable regions. This geopolitical situation will increasingly force nations to look for alternative sources. The ocean contains nearly all elements from the periodic system, but the exploitation of them will interfere with the marine ecosystem. Low-impact deep sea mining may prove to be the solution. But how are we going to arrange this in a sustainable way – and above all – how are we going to monitor and enforce this?

Many experts believe that in 2050 we will be using renewable energy, having (nearly) abandoned the exploitation of oil and natural gas. The ocean can play a role here as well, by supplying solar, tidal and flow energy. By linking the exploitation of energy to the location of use (use it where it is found, namely at the ocean farm or on the offshore platform) energy transport will become, at least partly, a thing of the past. The challenge, however, is finding a cost-effective solution for the transport and storage of renewable energy.

The extraction of renewable energy from the ocean will reduce the emission of greenhouse gases. Better still, by making transport of energy over

the ocean more sustainable, reducing the CO<sub>2</sub> footprint of food production and closing production chains, we may actually be able to reduce the emission of CO<sub>2</sub> through human activity to zero.

Since we will not be able to stop climate change, we have to consider climate adaptation. If specific regions on earth become uninhabitable in the future while energy is nearly free, the large-scale production of drinking water through desalination becomes an interesting possibility, especially if we use the remaining salt as building material (this is possible, see p. 77). Some think that the solution will come from geo-engineering, e.g. by enhancing the buffer function of the ocean for CO<sub>2</sub>, but it may also be worthwhile to bundle carbon into fibres (see p. 71).

The sustainable management and use of the ocean in 2050 will require global arrangements about the fair distribution of the natural resources. This means we have to start thinking about governance of the ocean as a whole, and not only by authorities, but also by citizens. The solution may be an international organisation that will enforce responsible use of the ocean through legislation, but this seems unattainable in the short term and also requires global monitoring, knowledge development and enforcement. Global governance seems the best option, not just for the sustainable exploitation of the ocean, but also to prevent a large-scale military conflict resulting from an unbridled race for natural resources. If all nations are represented in an Open Ocean Council that is able to allot concessions, this organisation should be able to distribute a fair share of these concessions among poorer nations. An Ocean Bank could stimulate the sustainable use of the ocean, whereas the Ocean Cadastre would deal with issues of ownership.

Ocean City, the vision of the future in Chapter 8, presents a possible solution: floating cities that are entirely self-sufficient and sustainable. Many technologies treated in this futures study can be found in this example, from flow energy to the reclaiming of waste from the ocean. Food could in this example be provided by the ocean farms, and fishing would be regulated – and strictly so – by the Open Ocean Council. Unless it is a real necessity, deep sea mining would be prohibited in order to preserve marine ecosystems.



Exhausting the ocean or leaving it be, these are the two extreme ends of the spectrum. The solutions provided by this futures study are generally positioned in the middle. The first thing we need is national action to combine all the knowledge and ideas spread across a myriad of stakeholders. But international action is just as crucial in view of the current scattered international policy and legislation on the ocean. The most profitable approach probably is to combine the various uses of the ocean (food, raw materials and energy), which will require system integration as well as (inter)national cooperation.

It is clear that the ocean can help us solve the two grand societal challenges of the next 35 years that formed the subject of this study, namely the supply of natural resources and dealing with the effects of climate change, provided that the ocean is preserved and used in a sustainable way. We should start now. Solid international agreements and an organisation that will be responsible for policy, monitoring and enforcement are still a distant prospect. But once they are in place we may be looking at an ocean of opportunities.



The concise explorative futures study *An Ocean Full of Opportunities* by the Netherlands Study Centre for Technology Trends (STT) addresses the possibilities of the open ocean. How can the open ocean contribute to the way we deal with the grand societal challenges of the next 35 years? Will the ocean provide solutions for (some of) these challenges? Nobody can predict the future. But we can reflect on it. In fact, we have to. The future starts today and we have to be prepared for it.

## Why this study?

During the first interviews about the original theme of a preliminary survey ('the future of water') practically none of the respondents mentioned the ocean. Perhaps because the United Kingdom is blocking our view of the Atlantic Ocean? Apparently the ocean is a blind spot for many people in the Netherlands. This is strange, because the ocean covers more than two-thirds of the surface of the earth, and it is very important for our well-being and prosperity.

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*'The world's oceans [...] drive global systems that make the Earth habitable for humankind. Our rainwater, drinking water, weather, climate, coastlines, much of our food, and even the oxygen in the air we breathe, are all ultimately provided and regulated by the sea. Throughout history, oceans and seas have been vital conduits for trade and transportation.'*

[UN, 2015]

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We owe much of our prosperity to the ocean. Centuries ago technology enabled the Dutch to defy the oceans. They used it for direct food supply – e.g. larger catches further away from the coast – and international trade. From the last century onwards, oil and gas extraction from the sea and from the ocean supplies crucial raw materials to the petrochemical industry, which in turn through the production of plastic lead to a wide range of products, . At present researchers are investigating whether the aquaculture



of seaweed and oysters in demarcated zones can contribute to meeting the increasing demand for (high-protein) food. And there are new opportunities, such as sea mining of scarce resources, the extraction of energy (e.g. through ocean thermal energy conversion, OTEC), the production of drinking water through desalination and perhaps also the use of the ocean as a place to live on, or in the far future perhaps even under water.

### Did you know that...

...algae at the surface of the ocean produce 70 percent of the oxygen on this planet? [Ecomare, 2015]

...the ocean covers 71 percent of the surface of the earth? [NOAA, 1015]

...the ocean contains 97 percent of the water on earth? [NOAA, 1015]

...more than 95 percent of the underwater world is still uncharted? [NOAA, 1015]

...the largest abundance and diversity of life is found at or below the surface of the seas and the oceans? [Earle, 2009]

### Research question

If the influence of the ocean on the functioning of the global natural systems – crucial for mankind – is so vast, is it then also possible that the ocean contributes to potential solutions for the grand societal challenges of the future, such as climate change and food security? Figure 1 shows the relationships between the ocean and the grand societal challenges of the future as experts and stakeholders in the field see them. Taking into account our relative unfamiliarity with the ocean and the important role it plays in our existence, as well as the grand societal challenges up to 2050, this explorative study addresses the question: How can the ocean contribute to the way we will deal with – and hopefully solve – some of the grand societal challenges of the future? An online questionnaire among experts and stakeholders concretised this to:

**How can the ocean contribute to the supply of natural resources and the dealing with the effects of climate change in 2050, and still be preserved and used in a sustainable way?**



forming part of this explorative futures study (see Appendix 3. Structure of the survey). This publication does not address the technological feasibility, ecological desirability and administrative workability of the various ideas presented. This would require more extended (scientific) research (for more information, see the Reflection).

### Scope of the study

This survey specifically addresses the open ocean and not the littoral areas. In our definition the open ocean is the part of the ocean falling outside the jurisdiction of the EEZ (Exclusive Economic Zone) of nations. The area addressed lies far beyond the coastline (outside the continental shelf). It includes the space above, at and below the water surface.





In the concretised research question preservation and sustainability form a prerequisite for the ideas on the possibilities the ocean offers for supply of natural resources and dealing with the effects of climate change. Our definition of sustainability is derived from the World Commission on Environment and Development in the report *Our common future*: “Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.” [UN, 1987] Applied to the ocean this means that natural resources should be extracted in such a way that they are not exhausted, but remain at a sustainable level. At the same time the activities needed to extract these renewable natural resources should not cause disturbances in the marine ecosystem, because this could endanger the ecosystem services supplied by the ocean (see also Chapter 1 and 2).

The visions of the future in Part 2 of this publication focus on sustainable use (balance between usefulness for mankind and preservation of the ecosystem). Other futures are equally possible. For this reason the text also includes remarks on these alternative visions of the future, e.g. about the threats to the ocean (overexploitation) and about what happens if we do not act.

The time horizon of this explorative study is 2050. STT uses the input of participants to sketch the various possible futures. In a sense the ideas and visions of the future presented in this publication are answers to the simple question: “What if...?” Some ideas may become reality before 2050 (e.g. the reduction of bycatch through sonar technology), or at a later stage (floating cities on the ocean). The choice was made to present an image of the future possibilities of the use of the ocean that is as complete as possible, for which reason all ideas are included, also unsustainable exploitation.

In the search for an answer to the research question, the focus was on both the possibilities of technology and the role of governance to enable the sustainable use of tomorrow’s ocean.

## The use of a futures study

In part 2, this publication describes possible visions of future sustainable use of the open ocean. Why survey the future? Because thinking about the future makes us aware of the opportunities and threats of today. One of the aims of this study is to identify challenges and opportunities of technology in the oceanic space (see page 15, Aim 2). The ideas in this publication on how to use the ocean of the future in a sustainable way contribute to an increased awareness of and preparation for the fundamental uncertainty of the future. Businesses, research institutes and governments can in this way prepare for the various challenges posed by the future. The threats, however, tell us what will happen if we do nothing. Reflecting on the future creates awareness of the possible scenarios and how to act in the best way. It enables us to respond to change at the earliest possible stage. Or, to quote the STT motto: 'To make our society future-ready'.

## Method

This publication is the result of an explorative futures study in which within a short timespan an intensive effort was taken to collect ideas on the ocean in 2050 through interviews, online questionnaires and workshops. For more information on the structure of this study, see Appendix 3.



### Part 1: Current developments and context

**Chapter 1. The open ocean** discusses the special characteristics of the ocean, why the ocean is so important for mankind and what the present threats to the ocean are.

**Chapter 2. The ocean and related grand societal challenges** shows which of these challenges, according to experts, may be partly solved by the ocean. These are ‘supply of natural resources’ and ‘dealing with the effects of climate change’, the prerequisite being the preservation and sustainable use of the ocean. These themes provide the framework for the visions of the future presented in Part 2 of this book.

**Chapter 3. Technological developments** addresses the current developments in marine technology, including expectations about the application of these technologies in the ocean of the future. The technologies described in this chapter are also present in the visions of the future in Part 2.

### Part 2: The ocean in 2050 – A dive into the future

**Chapter 4. Extreme visions of the future** looks at the extremes of the spectrum: maximum exploitation or leaving the ocean alone. It seems obvious one should look for the middle ground.

**Chapter 5. Supply of natural resources** gives an overview of the ideas on how in 2050 the ocean – aided by technology – can supply food, energy and raw materials in a sustainable manner.

**Chapter 6. Dealing with the effects of climate change** shows how in 2050 the ocean can contribute to dealing with the effects of climate change. The possible solutions are found in three categories: reducing the emission of greenhouse gases (climate mitigation), adapting to the effects of climate change (climate adaptation) and active interference in the climate through geo-engineering.

**Chapter 7. Sustainable management and use of the ocean** aims at the future role of governance in the preservation and sustainable use of the ocean. This chapter addresses a number of themes, from monitoring and enforcement to the role of citizens and international (governmental) organisations of the future.

**Chapter 8. Vision of the future: Ocean City** sketches a world in which sustainable technology and governance enable us to extract natural resources from the ocean without affecting the marine ecosystem. The ocean also helps us to deal with the effects of climate change. The ideas presented in Chapter 4-7 are integrated in a story that describes a possible image of our relationship with the ocean in 2050.

**The Reflection** offers guidelines for action, the keywords being national debate and international policy, knowledge development and smart combinations, once again underlining the necessity of relevant pilot studies.

## Target audience

This publication aims at everyone with an interest in the future of the ocean, but most specific at readers from trade and industry, research institutes and non-governmental organisations with an interest in the ocean.

Readers who are relatively new to this domain or only indirectly involved in it may benefit from the overview of the functions and possibilities the ocean offers.

Part 1 describes for those readers who are interested in the future of the ocean the context and current developments.

The visions of the future described in Part 2 may inspire stakeholders from trade and industry to reflect on how future technology may contribute to the sustainable use of the ocean. It may help them to identify the opportunities for (and threats to) their specific sectors.



The Reflection highlights the fact that we need knowledge development to enable sustainable use of the ocean. Research institutes may be inspired by the vision of the future in this publication to address themes in areas where their research could contribute to a sustainable ocean of the future.

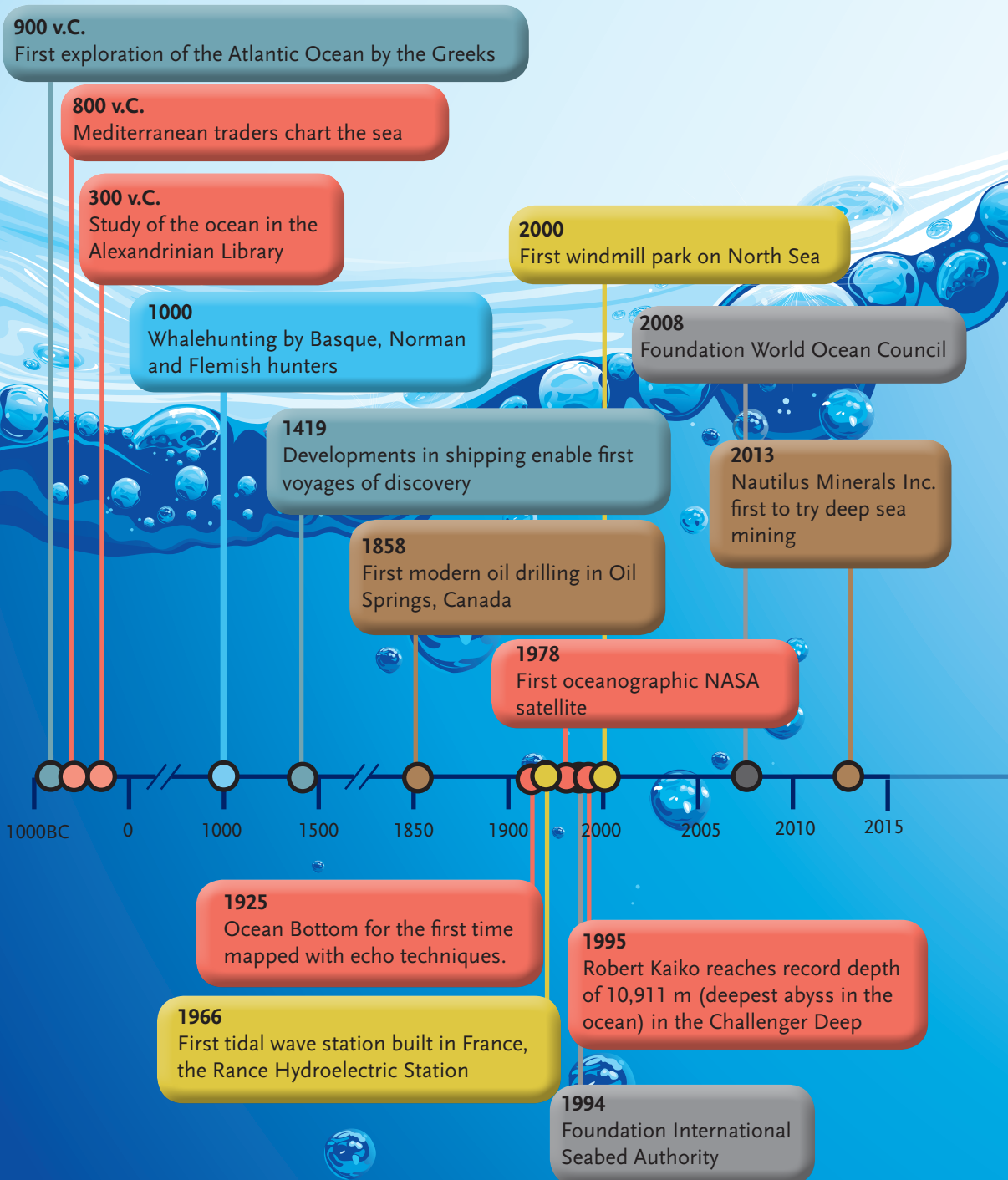
Policymakers may find the guidelines for the preservation and sustainable use of the ocean in Part 2 useful to stimulate innovation by the industry.

Non-governmental organisations may use the visions of the future to stimulate the national debate on the possible transition to sustainable use of the ocean, to put it on the political agenda and to alert trade and industry to their responsibilities in this domain.



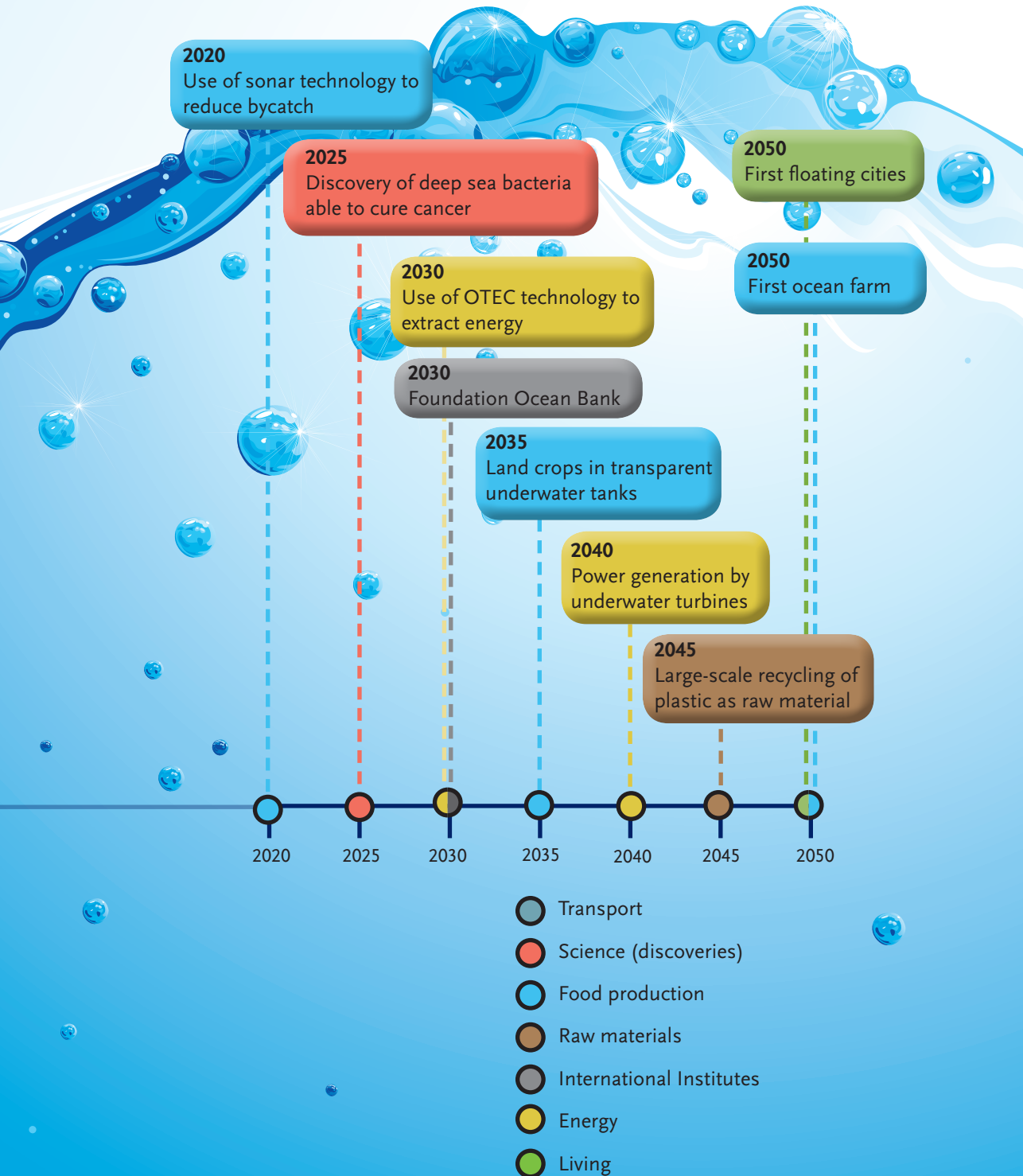
## INTERMEZZO

# Mankind and the ocean then...



# ...and in the future

Milestones of the future









An underwater photograph showing a large, dark fishing net draped over a coral reef. The net is made of a fine, dark mesh and is partially covered in green algae. In the foreground, there are various types of coral, including a large, brown, brain-like coral on the left and a smaller, green, branching coral in the center. A small, yellow and white striped fish is visible in the bottom left corner. The water is a deep blue color.

# PART 1

## CURRENT DEVELOPMENTS AND CONTEXT

Part 1 offers a selection of the current knowledge on the ocean and the relevant trends, the grand societal challenges and the technological developments. It is not possible to include all relevant knowledge and developments. That is why the end of Part 1 refers the reader to external sources (literature, initiatives and organisations).

An underwater scene with a fishing net in the upper left and coral in the lower left, set against a deep blue background.

## Set up Part 1

### *Chapter 1. The open ocean*

- ~ Characteristics of the open ocean
- ~ Ecosystem services by the open ocean
- ~ Threats to the open ocean

### *Chapter 2. The ocean and related grand societal challenges*

- ~ The ocean as the solution for grand societal challenges
- ~ Supply of natural resources
- ~ Climate change
- ~ Preservation and sustainable use of the ocean
- ~ Current developments in sustainable ocean policy

### *Chapter 3. Technological developments*

- ~ Types of technologies
- ~ What are our expectations and wishes?

### *Further reading*

- ~ Literature
- ~ Initiatives and organisations

---

*'Even if you never have the chance to see or touch the ocean, the ocean touches you with every breath you take, every drop of water you drink, every bite you consume. Everyone, everywhere is inextricably connected to and utterly dependent upon the existence of the sea.'* [Earle, 2009]

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# CHAPTER 1.

## THE OPEN OCEAN

The 21st century is also referred to as the ‘Age of the Ocean’. Technological developments and progress in collecting, sharing and analysing research data give us an increasing insight into this ‘blue world’. The knowledge and insights gained from these data show that the ocean plays a crucial role in the well-being of our planet. But pollution, overexploitation and other forms of irresponsible use threaten the ocean’s health, and with it our own well-being. This chapter offers a brief overview of the characteristics of the open ocean, the ecosystem services it supplies to mankind, and the present threats to the ocean.

### Characteristics of the open ocean

The ocean is a fascinating world of endless distances, unknown depths and a fantastic diversity of life. These and other characteristics of the open ocean create the conditions that determine which organisms can live where. They contribute to the ecosystem services supplied by the open ocean. On the other hand, conditions such as the high salinity, pressure, depth and lack of light may also create technological challenges when exploiting the open ocean, or offer opportunities, such as the application of high pressure for energy extraction.

#### *A blue world*

Photos from space show that ‘Earth’ is actually not the most fitting name for our planet. More than 70 percent of the surface of the earth is covered by water. With a volume of 1.3 billion cubic km the ocean is the largest ecosystem on earth.





*A satellite image showing the vast surface area of the oceans*

### *Unknown depths*

The ocean is not just a big container filled with salty water. The seabed is a varied landscape full of ridges (mountains) and troughs (trenches), especially where the tectonic plates meet. The deepest spot in the ocean is the Mariana Trench, where the ocean reaches a depth of 11 km below sea level.

### *Ocean currents*

A combination of wind, differences in salinity or temperature and the earth's rotation causes the circulation of the surface water of the ocean. A famous example being the Gulfstream in the Atlantic Ocean. The movements of the warm and cold water makes that the ocean currents influence the climate on earth. The nutrients hidden deep in the cool ocean water are transported by an upward flow at the coast ('upwelling'), which explains why coastal areas are so rich in food, such as (shell)fish.



## *Rich in life*

Most life on earth (80 percent) is located in the ocean. So far up to 200,000 different species have been discovered. The true number, however, is in the millions, because large parts of the ocean have never been explored. The ocean is also the place where the oldest life on earth is to be found. The oldest fossils found to date are marine stromatolites aged 3.5 billion years. Fossils found on land are merely up to 450 million years old.

## *Extreme conditions*

The ocean is a world of extremes. In areas showing volcanic activity we find so-called hydrothermal sources, underwater geysers spouting extremely hot water of sometimes 350°C, which is full of (poisonous) minerals. These minerals turn the water black, which is why they are also called black smokers. The conditions in these environments are so harsh that the organisms living there (especially micro-organisms) are referred to as extremophiles.



***Stromatolites***

## Ecosystem services by the ocean

The ocean is an essential part of system earth, enabling life for human beings. It is the driving force behind many large systems such as the climate system, the water cycle and the carbon cycle. Marine life is also an important food source. Globally, a total of ca. 3 billion people rely on the ocean for their daily subsistence. The market value of the food and raw materials from the ocean is approximately 3 trillion US\$ per year (5 percent of the global GNP). These and other services supplied by nature to mankind are called ecosystem services (see Box below).

### Ecosystem services

Ecosystems offer all kinds of useful functions to mankind, such as the supply of raw materials and food, climate regulation and water purification. Benefits people extract from ecosystems are called ecosystem services. [PBL, 2010]

The societal and economic interest of the many maritime activities is therefore high on the political agendas, which also applies for the EU, who see a 'sea of opportunities' in the development of an integrated maritime policy: "The well-being and prosperity of Europe depend on the maritime spaces a continent has: they are channels for European trade, regulate the climate, supply food, energy and raw materials en form a popular background as a place for living and recreation by European citizens." [Stel, 2012]

*'The world's oceans are key to sustaining life on the planet. The ocean constitutes a conduit for ninety percent of the world trade, and for connecting people, markets and livelihoods. In light of the ocean's interconnectedness, all nations of the world should strive to make the oceans places of safety and sustainability of maritime activities for all humankind.'* UN Secretary General Ban Ki-Moon [UN, 2012]

### Climate regulation

The ocean acts as a gigantic buffer against the rising temperature and the increased amount of greenhouse gases in the atmosphere. This means that the ocean plays a key role in climate regulation. In the past decades about 90 percent of the increased warmth on earth has been stored in the ocean.

The ocean is also the main location of CO<sub>2</sub> storage. It is estimated that approximately 40 percent of the human-induced CO<sub>2</sub> emission since the industrial revolution has been absorbed by the ocean.

### *Food supply*

The biodiversity is an important food source for mankind. About 3 billion people rely on the ocean for their primary proteins. The main high-protein source provided by the ocean consists of (shell)fish and crustaceans, although there now also is an increased focus on the production of seaweed and algae as an alternative food source.

### *Raw materials*

The (bottom of the) ocean contains many raw materials that may be extracted. The best known conventional raw materials are oil and gas. But the ocean also contains metals (including manganese, cobalt, nickel and copper), salts (including potassium and sodium) and building materials (such as sand and gravel). Nutrients from land (e.g. from agriculture) flow through rivers into the ocean where they are consumed by organisms at the bottom of the food pyramid, transforming sunlight into biomass such as algae. Since nutrients (e.g. phosphor) are becoming scarce on land, the ocean may prove to be a valuable new source. Reclaiming these nutrients would help create a closed nutrient cycle.



### *Genetic resources*

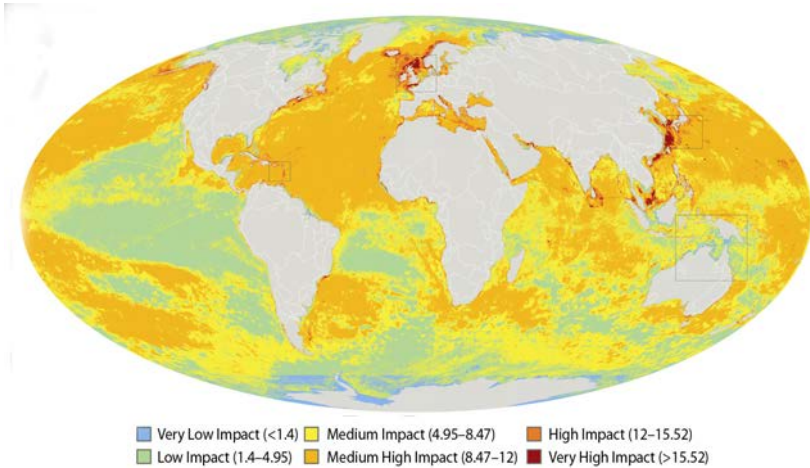
The rise of biotechnology increases the importance of genetic material and bioactive substances from marine organisms. In the open ocean, and especially near the hydrothermal sources on the seabed, organisms such as bacteria but also mussels and crabs are living in highly extreme conditions. The genes that enable them to survive are of the highest value for the development of medicine and the improvement of chemical processes. Between 1999 and 2015 the number of patents for genetic material from marine species has risen by 12 percent on an annual basis. The genes may be used in pharmacy, agriculture, food, cosmetics, etc.

### **Threats to the open ocean**

The economic and ecological possibilities and advantages offered by the ecosystem services of the ocean are under pressure. Technological progress has enabled activities at an increasingly larger scale, further away from the coast and in deeper water. More than 40 percent of the ocean is impacted by human activity (Figure 2). The effects are not only positive. Large-scale







**Figure 2** *The effects of human activities (such as fishing and pollution) on oceanic ecosystems. Blue: human influence has very low impact; red: human influence has very high impact. Image and data courtesy of Ben Halperns and colleagues [Halpern et al., 2013]*

fishing has led to overfishing. Marine ecosystems are affected by unintended bycatch and damage to the seabed. Oil and gas extraction and (the future) sea mining activities also contribute to the disturbance, temporary or not, of marine ecosystems. Finally, due to human activity on land the ocean has also become an inadvertent garbage bin. (e.g. the plastic soup). And the acidification of the ocean caused by the larger intake of  $\text{CO}_2$  by the water and the atmosphere; both have an impact on the food chain and oxygen production.

### Warming

The ocean acts as a gigantic thermal storage. In the past 100 years the temperature of the surface water has risen by  $0,7^\circ\text{C}$ . Higher temperatures affect the physiology of marine organisms and the geographic distribution of species, which also has an effect on commercially interesting species such as codfish. It is practically certain that the rise of the temperature contributes to the decline of this species in the North-Atlantic Ocean. This rise also reduces the capability to absorb  $\text{CO}_2$ , which in turn has a negative impact on the climate regulation by the ocean. The increased temperature also causes the sea level to rise, which will affect the coast (this study focuses on the open ocean, meaning that the sea level rise has not been taken into account).



### *Overexploitation*

### *Acidification*

The higher concentrations of CO<sub>2</sub> in the air lead to acidification of the ocean. Since the beginning of the industrial revolution the acidity of the upper layers of the ocean has risen by 30 percent (0.1 pH). Acidic water is a massive problem for crustaceans and animals with a calcium carbonate skeleton (such as mussels, coral and various species of plankton), because this material dissolves if exposed to acid. The increased acidity of the water also has an effect on ecosystems and biochemical cycles.<sup>1</sup>

### *Pollution*

Waste is responsible for the death of ca. 1 million seabirds and 100,000 marine mammals per year. Part of this waste comes from human activity on the ocean (oil and gas extraction, shipping and aquaculture), but 80 percent

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<sup>1</sup> The natural cycles of essential elements such as carbon, sulphur and nitrogen.

of the marine pollution is caused by human activity on land, including fertilisers, herbicides, sewage, plastic, radioactive material and oil.

### *Habitat degradation*

As a result of e.g. fishing methods or the extraction of minerals, marine ecosystems are affected which in turn affects life and biodiversity in the ocean. Habitat degradation is also caused by other factors, like acidification, less oxygen and warming of the ocean.

### *Overexploitation*

The growing population, now increasingly becoming middle class, causes a growing demand for natural resources. The demand for saltwater fish as a source of protein has led to 87 percent of the ocean being fully exploited, overexploited, or exhausted. In the past 40 years the fish stocks in the deeper parts of the Atlantic Ocean have decreased by 72 percent.





## CHAPTER 2.

# THE OCEAN AND RELATED GRAND SOCIETAL CHALLENGES

**Tomorrow's world is facing a number of vast challenges, like the feeding of an ever increasing global population (expected to be 9 billion people in 2050); the transition to 'clean' energy; more sustainable use of scarce raw materials; rising sea level; and climate change. These challenges are often referred to as grand (societal) challenges.**

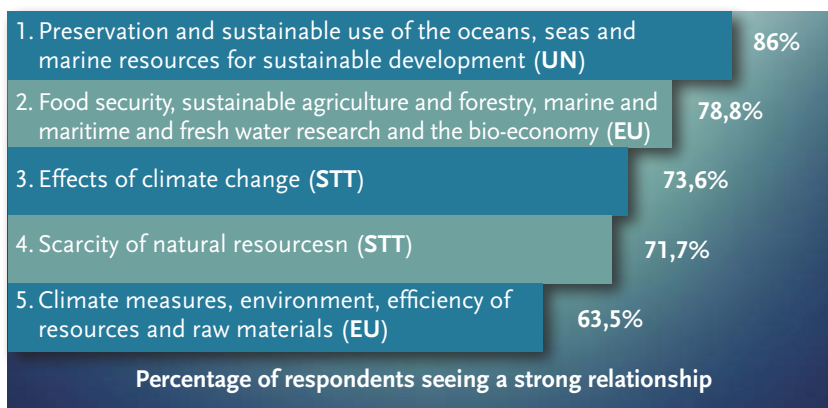
In 2009 the EU called for joint action concerning these challenges (the Lund Declaration): “The global community is facing Grand Challenges. The European Knowledge Society must tackle these through the best analysis, powerful actions and increased resources. Challenges must turn into sustainable solutions in areas such as global warming, tightening supplies of energy, water and food, ageing societies, public health, pandemics and security. It must tackle the overarching challenge of turning Europe into an eco-efficient economy.” [EU, 2009].

Since the ocean has so much influence on the conditions of our living environment (see Chapter 1) the question is whether it can also contribute to a solution for some of the grand societal challenges (the main question of this study). This chapter shows where, according to experts, the ocean can contribute, and what the role of the characteristics, ecosystem services and threats as described in Chapter 1 would be. The three themes described in this chapter provide the framework for the visions of the future in Part 2.

### **The ocean as the solution for grand societal challenges**

In an online questionnaire experts were confronted with a list of grand societal challenges from three important reports: the EU Horizon 2020, the STT Horizon Scan 2050 and the UN Sustainable Development Goals (see Box below). The question was: for which challenge would the open ocean offer a solution? The result were as follows:

*Top 5 of grand societal challenges for which the ocean can provide potential solutions (results of online questionnaire).*



EU = EU Horizon 2020, STT = STT Horizonscan 2050 en VN = UN Sustainable Development Goals.

On the basis of these results two challenges were selected for further study in this study:

**Challenge 1: Supply of natural resources (such as food, raw materials and energy)**

This is a combination of the challenges:

- ~ Food security, sustainable agriculture and forestry, marine and maritime and fresh water research and the bio-economy (EU)
- ~ Scarcity of natural resources (STT)
- ~ Climate measures, environment, efficiency of resources and raw materials (EU)

**Challenge 2: Dealing with the effects of climate change**

This is a combination of the challenges:

- ~ Effects of climate change (STT)
- ~ Climate measures, environment, efficiency of resources and raw materials (EU)

*‘The future ocean will affect all aspects of life. Therefore, it can be said that each great societal challenge is connected with the ocean and its ecosystem services. This doesn’t mean that the ocean will provide THE solution for these challenges. It is more probable that it will provide one of many solutions (and not necessarily the most important one). Also, the open ocean is not just a source for the possible solution or mitigation of great societal challenges, because at the same time the great societal challenges pose a threat to the open ocean and its ecosystem services.’*  
[respondent questionnaire]

A prerequisite for the contribution of the ocean to these two challenges follows from the first challenge in the top 5, namely the preservation and sustainable use of the oceans, seas and marine resources for sustainable development (UN).

## Reports on grand societal challenges

### **EU Horizon 2020**

Horizon 2020 is a European financing programme for research and innovation. The programme is aimed at the priorities set forward in the *Europe 2020 Strategy* of the European Commission, and deals with the primary concerns of European citizens. Horizon 2020 aims at seven challenges, including food security, clean energy and security. [EC, 2015]

### **STT Horizon Scan 2050**

The STT Horizon Scan 2050 describes six grand societal challenges in connection with the year 2050, including scarcity of raw materials, demographic changes and the effects of climate change. These challenges are all linked to signals for change that are already visible, such as robotics, programmable matter and the rise of artificial food. [STT, 2014]

### **UN Sustainable Development Goals**

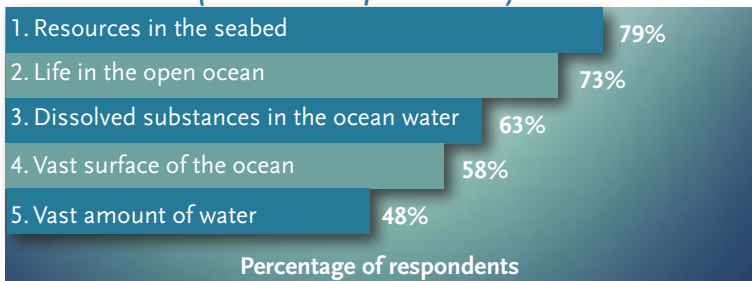
The third set of challenges consists of the UN Sustainable Development Goals. These 17 goals have been accepted by the General Assembly of the UN in 2015 and are designed as the follow-up on the UN Millennium Goals. These goals concern poverty, water supply and economic growth, etc. [UN, 2015]

## Supply of natural resources

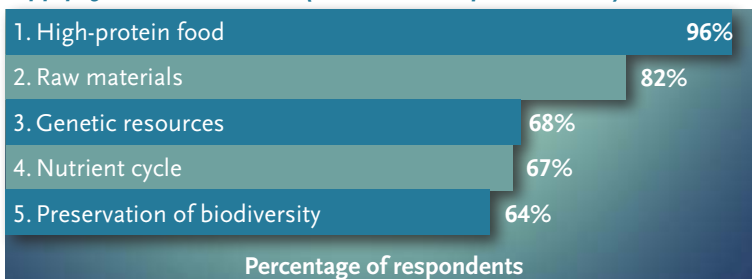
Economic growth in Western nations, but also in the rising economies, causes an increased global demand for energy, water, food and raw materials. But these resources are exhaustible. Also, many raw materials are found in politically unstable regions, meaning that many suppliers are looking for other regions that ensure a more stable supply of these raw materials.

The supply of natural resources by the ocean – such as food, drinking water, energy, raw materials and minerals – is vast. Resources in the seabed, life in the open ocean and the ecosystem service food supply contribute to that. The sustainable management of these natural resources is essential to secure availability to future generations. The top fives below show the characteristics and ecosystem services which according to experts contribute to the supply of natural resources.

### *Top 5 of characteristics of the open ocean contributing to the supply of natural resources (results online questionnaire).*



### *Top 5 of ecosystem services of the open ocean contributing to the supply of natural resources (results online questionnaire).*





## Climate change

The increased percentage of greenhouse gases in the atmosphere leads to climate change. This has a large global impact. Experts foresee that specific regions will become uninhabitable. Weather conditions may become more unstable and extreme, resulting in a greater risk of severe hurricanes and disastrous floods. Cities at the coast may disappear into the sea. Climate change forces us to face the challenge of keeping earth habitable for future generations.

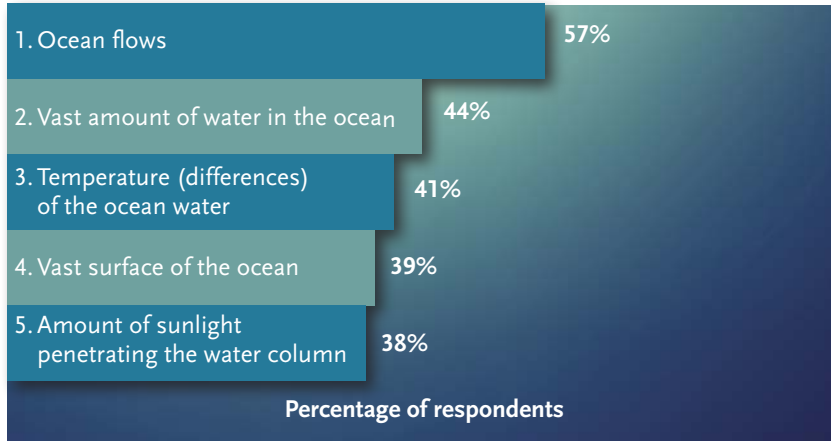
The ocean has through its buffer function<sup>2</sup> a direct influence on the climate, meaning that the ocean already contributes much to the mitigation<sup>3</sup> of climate change. Stimulation of this buffer function through geo-engineering (see Chapter 3) may help slow down the speed of climate change. For instance, by means of the iron fertilization technique, iron is added to the ocean water to stimulate the growth of algae, and thus increase the intake of CO<sub>2</sub>. There is, however, much controversy about both the feasibility and desirability of measures such as these. The ocean can also contribute indirectly to dealing with the effects of climate change through the supply of food and energy and by creating living environments on the water. These functions contribute to the first challenge: the supply of natural resources. The top fives on the next page show which characteristics and ecosystem services of the ocean according to experts contribute to the dealing with the effects of climate change.

Prior to the recent climate negotiations in Paris (December 2015), during a meeting on the importance of the ocean for our climate, Jose Maria Figueres (Co-Chair of the Global Ocean Commission) stated: “Today we are here to celebrate the ocean as well as the fact that the ocean receives its place in the climate debate. The ocean is the foremost driving force behind our climate and the natural systems, and also responsible for half of the oxygen that we breathe. By absorbing 90 percent of the superfluous warmth and 25 percent of the carbon we produce the ocean has saved us – and will continue to do so – from much more intense and accelerated effects of climate change. We must cherish and protect the ocean, because the ocean – today and any other day – extracts 4 kilo of CO<sub>2</sub> per person of everyone on earth from the atmosphere, and that is why we should care for the blue part of our planet.”

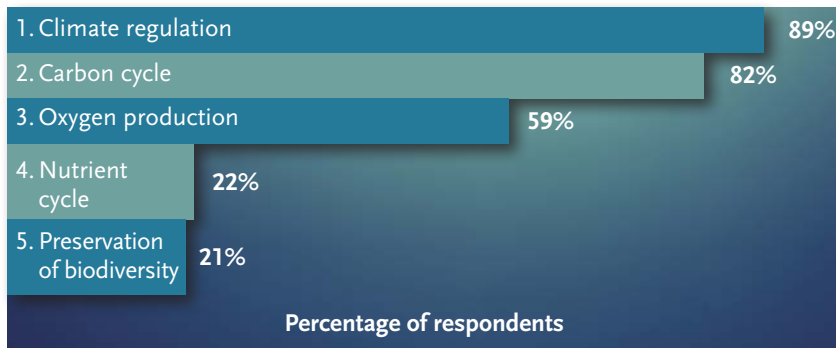
<sup>2</sup> A regulating mechanism that mitigates the effects of change.

<sup>3</sup> Mitigation is the reduction of the effects of climate change.

*Top 5 of characteristics of the ocean contributing to the dealing with the effects of climate change (results online questionnaire).*



*Top 5 of ecosystem services of the ocean contributing to the dealing with the effects of climate change (results online questionnaire).*



## Climate change is not new

During the Ice Ages the sea level was much lower than today. The North Sea was dry, providing a living environment for people and animals, including sabre-toothed cats, giant deer and mammoths. The warming of earth caused the sea level to rise, flooding the area between England and the Netherlands.

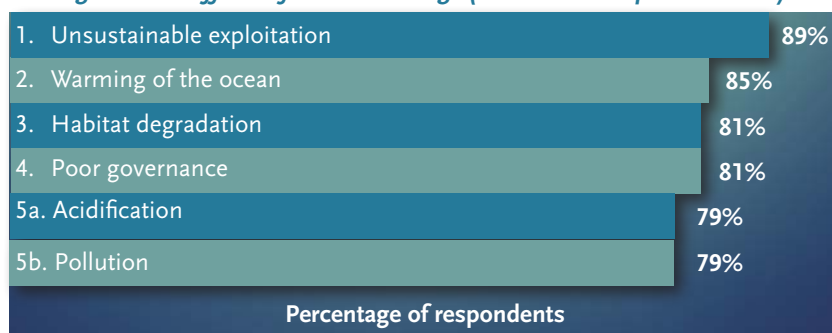
Climate change is therefore not a new phenomenon, but its impact may be vast.

*"We can only build a sustainable future in which people will feel well if the ocean stays healthy." [respondent questionnaire]*

## Preservation and sustainable use of the ocean

The ocean contributes to the supply of natural resources as well as to dealing with (the effects of) climate change, but this situation can only last if we make sustainable use of the ocean. For this reason it is high time to counter the present threats to the functioning of the ocean. Experts believe that overexploitation and warming of the ocean are the two most important threats, directly followed by habitat degradation, acidification and pollution (See Top 5 below).

### *Top 5 of developments threatening the supply of natural resources and the dealing with the effects of climate change (results online questionnaire).*



The ocean is a common good of the global population. This increases the chance of overexploitation and makes the sustainable use and management of the ocean more difficult. This mechanism is described in the theory *The tragedy of the commons* (see Box on the next page). This theory states that full freedom in the use of common goods in combination with maximising individual profit will lead to overexploitation. One way to prevent this is to implement management tools, e.g. fishing quota. One other important step is creating awareness. Most people are simply not or hardly aware of the importance of the ocean.

*'Many people are hardly aware of the importance of the ... ocean in their daily lives and the impact it has on human well-being; ... and the necessity to protect crucial resources in the ocean.' [respondent questionnaire]*

## Tragedy of the commons

*Tragedy of the commons* is the process in which full freedom in the use of common goods leads to overexploitation. A classic example is fishing. For an individual fisherman it is advantageous to catch more fish than would be optimal for the fishing community as a whole. As a result the fisherman has a rich harvest, but the total amount of fish in the ocean decreases. The profit of the additional catch goes to the individual fisherman, whereas the cost is distributed among all fishermen. It is therefore lucrative to fish for more as long as the (shared) costs are lower than the yield. Since *all* fishermen will reason the same way they will continue in this manner until catching fish no longer generates any advantage. The result is overexploitation and decline of the fish stock.

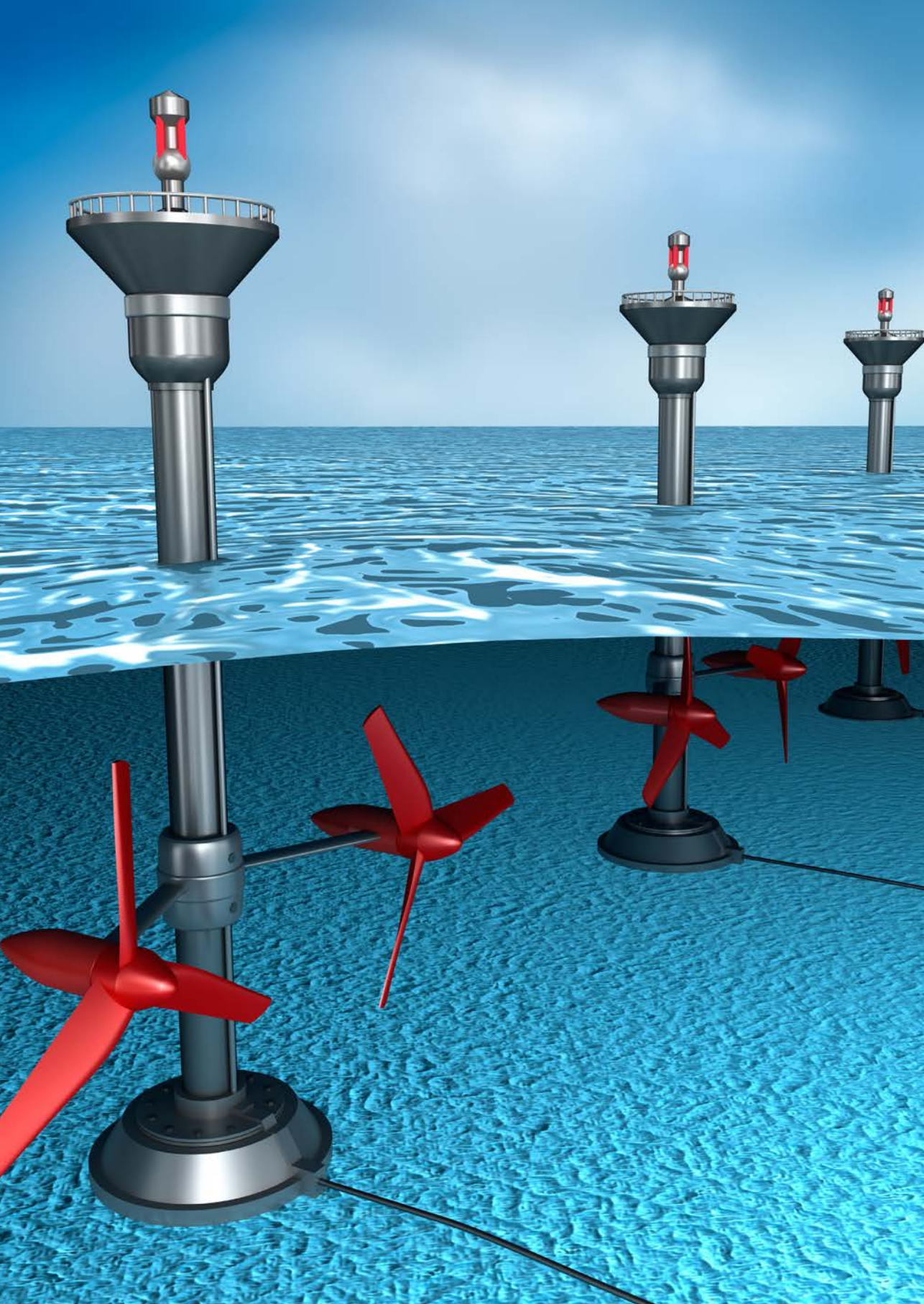
## Current developments in sustainable ocean policy

The past decade has seen an increased focus on marine and maritime governance, both in and outside the EU. For policymakers the main challenge is the sustainable use of the ocean to ensure that the natural resources and ecosystem services will also be available to future generations. At the same time they have to deal with the present needs of the growing global population and economic growth. That is why we see many EU and global initiatives to stimulate sustainable use of the ocean, e.g. the *EU Blue Growth Strategy* and the declaration *Because the ocean 2015*. For more initiatives, see ‘Further reading’ on p. 58.









## CHAPTER 3.

# TECHNOLOGICAL DEVELOPMENTS

The open ocean, and especially the deep sea, is still relatively unexplored territory. Technological developments, however, accelerate the exploration, exploitation and monitoring of the oceanic space, meaning that areas that could not be reached in the past have now become accessible, also to commercial activity. Technological developments play a role in the supply of natural resources, the dealing with the effects of climate change and the sustainable governance and use of the ocean. What types of technology are we talking about? And what is their expected and desired role in the ocean of the future?

### Types of technologies

The most relevant categories of technology are listed below. It should, however, be noted that a categorisation of technologies always includes overlap.

#### *Sensor technology*

Sensors are tools that are able to observe light, sound or any other physical quantity without direct contact. Sensor technology is already widely used to measure sea currents. The technology enables the ever quicker collection of ever more data. It is expected that this will contribute to the optimal charting of the marine (eco)system. Examples of the present developments include the use of sensor technology at extreme depths (below 2,000 m) and the use of autonomous minisensors to measure biochemical, biological and ecosystem variables.

Lab-on-a-chip technology (the integration of various lab functions on a chip of a few square cm) makes it easy to detect the presence of e.g. specific (dissolved) substances in sea water in real time. Hyperspectral cameras<sup>4</sup> can detect strange objects and carry out inspections of (seabed) surfaces.

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<sup>4</sup> The human eye discerns three colours (red, green and blue). A hyperspectral camera can discern many different wavelengths, including those outside the visual spectrum (such as infrared and UV).

Sonar technology will in the near future be used for sustainable fishing (see Box below). Because of the vast surface of the ocean satellites will also be crucial, both to increase knowledge on the ocean and for monitoring. They can also assist in tracking & tracing (real-time positioning) of ships, meaning that people can follow ships live, for example on [www.marinetraffic.com](http://www.marinetraffic.com).

### **SOFIC – Sonar technology for selective fishing**

**by Maurits Huisman, TNO**

The prevention of undesired bycatch poses an ever larger challenge to the fishing industry, also since new EU policy obliges to bring the entire catch onshore. This means that the bycatch can no longer be discarded at sea, thus creating a greater need for techniques for selective fishing.

TNO, in collaboration with the shipping agent Jaczon (Scheveningen), developed a sonar system that enables the crews of trawlers (boats using funnelshaped nets) to distinguish between fish species. The prototype of broadband forward-looking sonar is able to classify fish, determining whether a shoal of fish contains herring, mackerel, etc. If the shoal contains little bycatch the crew can lay the nets. TNO developed a unique algorithm for fish recognition. Additional sonar data will enable improvement of the algorithm, and the extension to more fish species.

### *Information technology*

Under information technology (IT) we include all technology related to the collection, storage, processing, transport and management of data. Developments in IT are leading to smarter and autonomous systems, enabling e.g. rapid complex calculations and simulations. Improved and new monitoring techniques and international cooperation and exchange ensure that the data on the ocean keeps growing, meaning that our knowledge of the ocean increases rapidly. This knowledge helps us making better predictions of the impact of specific measures. This contributes to a much more sustainable use and management of the ocean.

The development of coastal areas and of natural resources from the ocean as well as the preservation of the marine environment require more knowledge on and intensive monitoring of the oceanic space. To determine the present and future state of the ocean we need a global marine information system.



This conclusion and the United Nations Conference on Environment and Development (UNCED 1992, Rio de Janeiro) started the transition to operational oceanography.<sup>5</sup> The development of a global monitoring and information system – the Global Ocean Observing System (GOOS) – forms its backbone. The monitoring of the ocean calls for high-tech solutions, such as satellites, smart buoys (Argo buoys), gliders and other drones, ROVs (Remotely Operated Vehicles) and acoustic thermometers. IT connects all the information from these instruments, using numerical models to produce information of great societal importance (Chapter 2). To make the best possible use of this information data platforms and agreements on data exchange are needed. The UNESCO International Oceanographic Data and Information Exchange (IODE) and the Marine Environment Data and Information Network (MEDIN) are some examples.

### *Robotics*

In the next decades, the influence of smart and autonomous systems will increase. There are already many different robots, varying from grippers and drones to microrobots. An autonomous robot is being developed that will also perform under extreme conditions, i.e. high pressure and heat. Robots will increasingly become smaller and move autonomously. It is expected that the future will see more attention given to e.g. navigation and manipulation in unstructured environments, such as the seabed. Due to the fact that a robot can perform in extreme conditions (being difficult or dangerous for human operators) robotics is already large-scale applied in the ocean, from monitoring to laying pipelines. Examples may be found on the website [www.seatools.com](http://www.seatools.com).

### *Smart materials*

Smart materials are materials that can change under external influences such as heat, humidity, acidity and electric and magnetic fields. These changes to obtain desired properties in applied material can result in e.g. ultra-absorbing material used to clean up dangerous substances (oil, poisonous substances), which will come in very handy if disaster strikes the ocean. Smart materials with ‘shape memory’ are already used in adaptive wings in the aircraft industry as well as for making steel structures in earthquake proof constructions. In the future these materials can also be used

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<sup>5</sup> Operational oceanography is the systematic and long-term routine measuring, including interpretation and distribution.



### *Robotics for maintenance of pipelines*

to reduce noise, to absorb dissolved substances, and for the separation and processing of plastic from the ocean. Especially composites made of fibre and artificial resin are highly suitable for use on the ocean. They are light, corrosion-resistant and durable. They show high mechanical values in relation to their weight and are relatively easy to repair.

### *Marine biotechnology*

Because of their exposure to extreme and highly diverse environmental factors such as high (or low) temperature, high salinity and varying water quality, marine organisms are able to produce unique substances. By using molecular biology, nanotechnology and bioinformatics, these marine organisms are deployed to develop biofuels, medicine and enzymes. Marine biotechnology is e.g. used in pharmacy, cosmetics, biomaterials, biomineralisation and aquaculture.

### *Filter technology*

Filter technology helps to extract substances from the ocean, and is therefore suitable for use in the marine environment to clean up pollutants or to extract nutrients and minerals from them. One way to filter (dissolved) substances from the water is membrane technology. (see Box).

## Membrane technology and desalination of ocean water

by Albert E. Jansen, Water Innovation Consulting

The most popular technology to desalinate ocean water is membrane technology. More than half of all installations rely on reversed osmosis, in which ca. 50 percent of water is extracted from the sea water after which the saltier flow is returned to the sea. A new membrane process is under development and now available for small-scale testing. It is called membrane distillation. It is based on heat, not electricity. In the industrial world this heat is available in the form of residual heat ( $< 90^{\circ}\text{C}$ ), whereas (sub) tropical countries can use solar heat. This technology appears to be promising for the future. One distinct disadvantage of all installations used to desalinate sea water is the return flow of the saltier water (sometimes also containing chemicals used to prevent scaling\*). This is already causing environmental problems in the Persian Gulf. The obvious solution is to process the salty water further into pure water and solid salt. Membrane distillation and evaporators could achieve this. In time, this technique could replace the current salt extraction method in the Netherlands, which increasingly leads to problems (soil subsidence and earthquakes).

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\* Scaling is the clogging up of the membranes.

### *Deep sea mining technology*

The exploitation of the bottom of the ocean is still in an explorative phase. Although some efforts to extract raw materials from this environment have been successful, the extraction of tons of raw materials from the seabed is still a major technological challenge, including transport to the surface. The first industrial mining operation at the bottom of the ocean is scheduled for 2018 in the EEZ of Papua New Guinea. The industry is also looking at the exploitation of methane hydrates and manganese nodules in the Clarion Clipperton Fracture Zone in the Pacific. At present, however, the technology has not progressed far enough for use at an industrial scale, and there are severe concerns about the environmental impact.

### *Transport technology*

Transport forms an important part of the maritime sector and within the transport sector innovation is high on the agenda. Sustainable and efficient transport is also one of the themes of the EU Horizon 2020 programme. New

materials, manufacturing techniques and advancements in IT will probably lead to new possibilities for automated transport as well as changes in the speed and efficiency of transport. More efficient engines and new fuels can make transport both more efficient and cheaper, and at the same time reduce the emission of CO<sub>2</sub>. New materials – lighter, stiffer and corrosion-resistant – will probably also improve the performance and durability of vehicles and vessels. Transport technology also extends to cables. For these the vast distances and great depths of the ocean pose major challenges.

### *Geo-engineering*

Geo-engineering is the large-scale manipulation of natural systems to counter the effects of climate change. In the ocean geo-engineering mainly aims at reducing the amount of CO<sub>2</sub> in the atmosphere. Methods include iron fertilisation (already applied on a small scale). Other possibilities for marine geo-engineering are the adding of nutrients; the stimulation of upwelling of deep, nutrient-rich ocean water; CO<sub>2</sub> injection in the deep ocean; and increased CO<sub>2</sub> intake by stimulating olivine weathering (settling of calcite). Geo-engineering is, however, surrounded by controversy. Many people believe it involves too many risks, since we are unable to really predict the effects it will have. Most techniques are thus far mainly suited for improving our knowledge on the natural system.

### **Clean technology**

**Clean technology** refers to the products, processes and services that contribute to sustainable management. The key concepts are limiting pollution, efficient use of energy, reduction of CO<sub>2</sub> emission and the use of renewable materials and energy whenever possible. Clean technology is, in other words, about the design and application of technology and has possibilities for the use of any technology used in or on the ocean. The Dutch Maritime Strategy 2015-2025, for instance, aims to reduce emissions by using alternative fuels for ships.

### *Building with nature*

How can we learn more from nature? In the so-called delta sector and in the maritime sector various projects (e.g. Protecting with Nature) are underway. In the future the issue will be how to make smart use of nature instead of working against its forces. To take the ecosystem and the services



it supplies as the point of departure rather than implementing technology to meet our own requirements. There is a growing insight that we can use nature as a starting point when designing solutions, think of coastal protection by dunes or oyster beds to counter erosion. The question is of course how we can apply this concept to the open ocean. To achieve this we will have to know more about the functioning of the marine ecosystem in order to make an optimal, sustainable use of it for the supply of food, raw materials and energy, but also for the dealing with (the effects of) climate change.

## Biomimicry

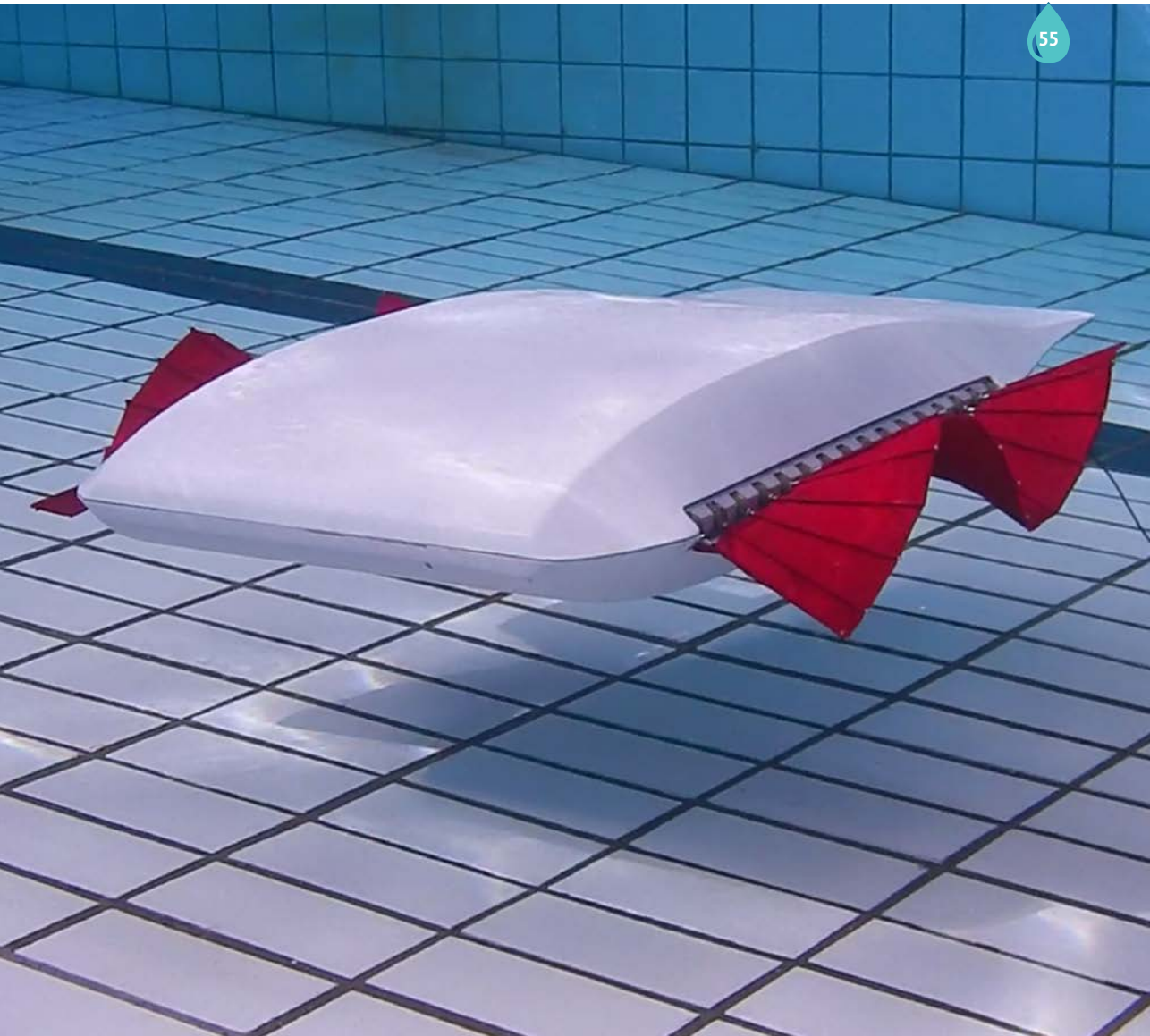
by Jan Hoegee, TNO

Apart from using ecological and biological processes to tackle issues such as water security and water quality, nature can also teach us how to approach technological designs. This is called biomimicry.

The chaos theory fundamentally changed our view of the universe, and biomimicry may do the same for life on earth. In short, biomimicry is nothing more than nature inspiring us to invent something new. Take, for instance, the miraculous examples of adaptation to the surrounding environment. Can these examples inspire us to develop efficient propulsion systems for ocean steamers? Think, for instance, of the nanolaminate structures that were inspired by the feathers of a penguin or the skin of a shark. Or of the superefficient propulsion systems derived from the tail of a whale or a dolphin (O-foil). Low resistance and high propulsion efficiency lead to very low energy use, which brings the application of resources with a very low energy efficiency within reach. For instance, the laying of pipelines is monitored by ROVs. By looking at the movements of the stingray it is possible to design these in such a way that they will have minimal impact on the seabed and marine life. In other words, the design of sustainable and future proof systems call for a link-up between various domains, in this case ecology, biology and technology. Nature makes us wonder, and inspires. Looking at living nature with an open eye will open doors to various smart marine technologies.

Innovations in ships such as the whale tail propulsion and nanoskin on the boat hulls for better streamlining show that tomorrow's designers will have to work across sectors, so shipbuilders and biologists together design and build new solutions.



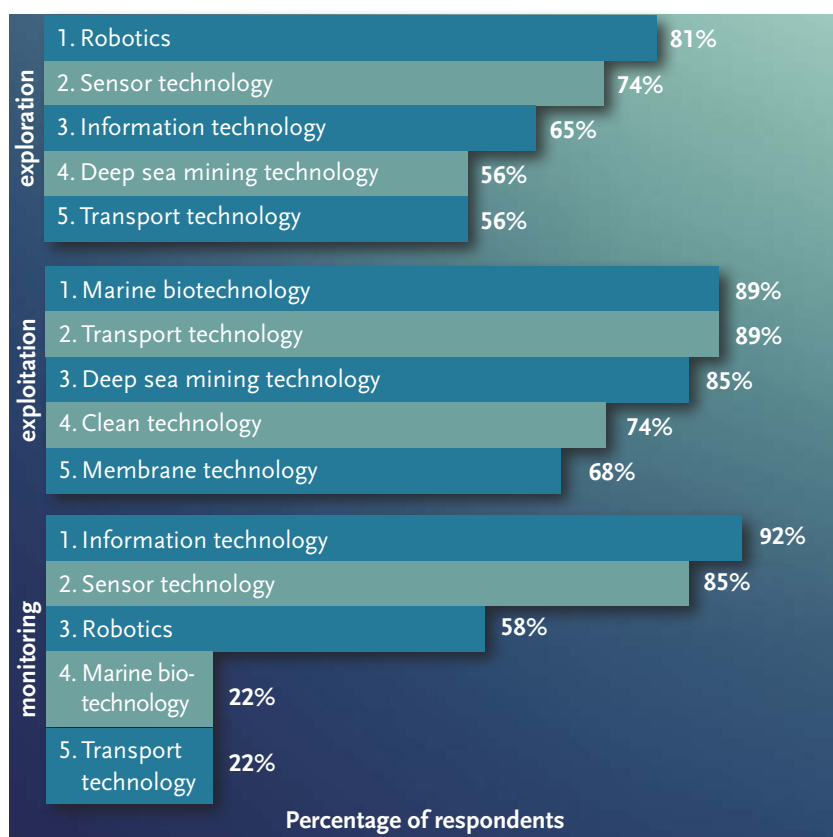


*Stingray test: A team from the universities of Delft and Wageningen studied the movements of the stingray in the ocean. The very low impact of its propulsion was then simulated in an underwater robot. This turned out to have the same low impact on the seabed, whereas propulsion efficiency was very high. Source: Galatea, WUR/TUD*

## What are our expectations and wishes?

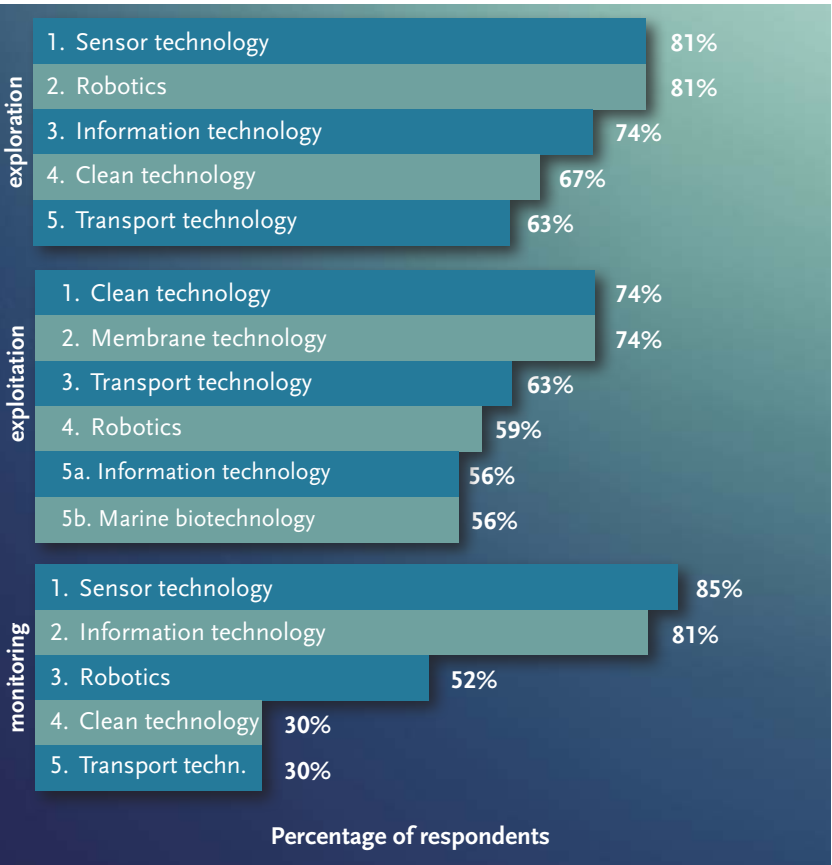
In the online questionnaire the respondents were asked which of the described technologies would be playing a vital role in the exploration, exploitation and monitoring of the ocean in 2050. As most likely technologies resulted: robotics and sensor technology (exploration), biotechnology, transport technology, deep sea mining (exploitation) and IT with sensor technology for monitoring (see Top 5 below). Likely technologies are, however, not necessarily also desirable technologies. According to the experts the most desirable technologies for exploitation would be clean technology and membrane technology. Investments in these two technologies would therefore potentially contribute to a sustainable future of the ocean. As far as exploration and monitoring are concerned the technologies that will most likely be used will match with the desired technologies (see Top 5 on the next page)

### *Top 5 of expected technologies for exploration, exploitation and monitoring of the open ocean (result online questionnaire)*





*Top 5 of desired technologies for exploration, exploitation and monitoring of the open ocean (result online questionnaire).*



The combination of technology and learning from nature creates great opportunities for a more sustainable approach to the ocean. Part 2 is about how the technologies described in this chapter can be applied for the sustainable use of the ocean, in order to exploit the natural resources and deal with (the effects of) climate change.

Below you will find a selection of the relevant literature, initiatives and organisations.

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- ~ TU Delft-platform Ocean Energy. <http://oceanenergy.tudelft.nl/>
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### *Europe*

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- ~ *Joint Programming Initiative Healthy and Productive Seas and Oceans*. [www.jpi-oceans.eu](http://www.jpi-oceans.eu)
- ~ Ocean Energy Europe. <http://www.oceanenergy-europe.eu/>
- ~ The European Marine Board. <http://www.marineboard.eu/>
- ~ The European Society for Marine Biotechnology. <http://www.esmb.org/>
- ~ Vectorsproject. <http://www.marine-vectors.eu/>

### *Worldwide*

- ~ *Because the Ocean Declaration*. <http://www.globaloceancommission.org/because-the-ocean/>
- ~ Global Ocean Commission. <http://www.globaloceancommission.org/>
- ~ International Forum for Deep Sea Mining Professionals. <http://www.deepsea-mining-summit.com/index>
- ~ International Seabed Authority. <https://www.isa.org/jm/>
- ~ Plastic Soup Foundation. <http://www.plasticsoupfoundation.org/>
- ~ UN Oceans Compact. [http://www.un.org/Depts/los/ocean\\_compact/oceans\\_compact.htm](http://www.un.org/Depts/los/ocean_compact/oceans_compact.htm)
- ~ *United Nations Environment Programme*. <http://www.unep.org/>
- ~ *United Nations World Ocean Assessment*. <http://www.worldoceanassessment.org>





A person is swimming underwater, viewed from below. Their arms are extended forward, and their legs are also extended, creating a streamlined shape. The water is dark blue, and there are some bubbles around the swimmer's head and arms.

## PART 2

# THE OCEAN IN 2050

## A DIVE INTO THE FUTURE

Part 2 describes how in 2050 the ocean can contribute to the solution for the great societal challenges 'supply of natural resources' and 'dealing with the effects of climate change', the prerequisite being that the ocean is preserved and used in a sustainable way. The ideas presented here are the result of creative workshops. They fit within a sustainable vision of the future, in which the use we make of the ocean goes hand in hand with the preservation of the ecosystem. Some of these ideas are already being developed, being aimed at the near future, whereas other ideas are much further away in time.

The visions of the future presented in Part 2 are meant to fuel the debate on the future of the ocean and the way we treat it, especially with regards to technological developments and governance. Are we really future-ready? How can we prepare for specific developments and what will be needed when some of the images described in this book become reality? Do we only have the choice between maximum exploitation and leaving the ocean be, or should we follow the middle of the road?

## Set up Part 2

*Intermezzo – Whenever I think of the ocean in 2050...*

### *Chapter 4. Extreme visions of the future*

- ~ The ocean as a sanctuary
- ~ Maximum exploitation of the ocean

### *Chapter 5. Supply of natural resources*

- ~ The ocean as a food source
- ~ Extraction of raw materials
- ~ Energy supply

### *Chapter 6. Dealing with the effects of climate change*

- ~ Climate mitigation
- ~ Climate adaptation
- ~ Intervention in the climate through geo-engineering

*Intermezzo – The ocean as a living environment*

### *Chapter 7. Sustainable management and use of the ocean*

- ~ Implementing policy
- ~ The role of citizens
- ~ International authorities

### *Chapter 8. Vision of the future: Ocean City*

### *Reflection*

- ~ Guidelines for action
- ~ Conclusion

~~~~~  
*'The most wonderful things are still waiting for discovery.'*  
[participant workshop] ~~~~~

## INTERMEZZO

# Whenever I think of the ocean in 2050...

...what did workshop participants think?

'It is my hope that in 2050 everything is neatly arranged, in the sense that the use [of the ocean] will be sustainable. But I fear this will not be the case.'

'In 2050 the use of the ocean will be much more intensive, but sustainable. People will not accept anything else.'

'It will become increasingly normal that activities associated with land – such as the generation of power or mining – will also take place at sea.'

'In 2050 no “storming of the ocean” has taken place due to the high cost of activities on the ocean. But there will be many developments in mining.'

'In 2050 we will have become more one with the ocean.'

'I expect we will see increased moving to the open ocean. (...) I imagine artificial islands, or underwater cities.'

'In the future the ocean and its natural resources will lead to large international conflicts.'



## EXTREME VISIONS OF THE FUTURE

The future visions of Part 2 show the possibilities that technology and governance offer for sustainable use of the ocean. The sustainable use of the ocean may be viewed as the optimum balance of possible human interferences with the ocean. But what about the extremes, maximum exploitation or leaving the ocean be? In this chapter we explain these extreme visions.

### The ocean as a sanctuary

“When I take my binoculars and look over the railing I can see a large shoal of orcas crossing my view at the horizon. Not so long ago this part of the ocean was in bad shape. Intensive fishing and deep sea mining had taken their toll. That has now completely changed. As far as I can see there are no fishing boats anymore and the former offshore platforms are now actually hotspots of biodiversity. Since the introduction of sustainable hyper-intensive farming, food is now cultivated in gigantic quantities – and very efficiently too – on land and near the coast. The circular economy caused the demand for raw materials to drop by 75 percent compared to 2035. The moment we left the ocean alone nature started blooming again. *The Blue Living Planet 2050 Report* has the proof: the global fish stock has skyrocketed. Fish species that were nearly extinct – such as the bluefin tuna – are back. Who would have thought this 35 years ago?”

Further exploitation and use of the ocean to solve our problems with energy and food security? This idea evoked resistance and concerns in most participants; according to them the ‘do no harm’ principle is a priority. It may be better to do little or even nothing than doing something of which we do not know the outcome. Besides, protection of the ecosystems and biodiversity in the ocean is important. In a sense the ocean is the ‘last wilderness’ on earth, and using the surface of the ocean as a building site or to start the large-scale extraction of natural resources was to some participants a depressing image: “Do we have to interfere with everything?” A strong need



was felt to keep specific areas on earth away from the sphere of human influence. In the future vision sketched above there is no active use of the ocean for the supply of natural resources or the dealing with the effects of climate change. Instead the ocean is left alone as much as possible, as the 'last wilderness' it is, and being so still making a sizeable contribution to our well-being. Leaving the ocean alone and actively stopping pollution enables the ocean to recover the very thing to do to make the ecosystem services such as climate regulation find their balance again.

*'The ocean already has so much to endure from mankind. It is a strange assumption that on top of that the ocean should contribute to the solution of our problems.'* [participant workshop]

### Remark

Leaving the ocean be does not imply that we do not have to do anything. Keeping nature intact requires active management.

## Maximum exploitation of the ocean

"The water splashes against the pillars. Due to continuous storm the construction of the new Pacific Platform is now weeks behind schedule. This deep sea mining platform will finally enable the mining company to reach the deepest part of the ocean. The demand for minerals from the bottom of the ocean has increased dramatically, but has also led to tension between world powers. Traditional deep sea mining turned out to be a goldmine. Its international status and the limited legislation have enabled the Deep Sea Solutions Company to grow substantially, although in a few years' time this may be over. The continuous threat of international conflicts over raw materials from the ocean have already forced the company to take very expensive defensive measures. The investments in an armed fleet has set the company back by billions, not to mention the water cannons needed to keep Bluepeace away from the platforms."

Although the participants in this study had many ideas on preservation and sustainable use of the open ocean, they indicated that daily practice shows another trend. Unsustainable exploitation endangers vulnerable ecosystems in the ocean to the risk of extinction. Ultimately this manner of exploitation will be disadvantageous for the entire global population, because it

threatens the ecosystem services supplied by the ocean. In accordance with the principle of the *Tragedy of the commons*, insufficient regulation of common goods – in this case the open ocean – leads to unsustainable exploitation driven by the need for individual gain, and following that a drop in the total output. The growing demand for food, energy and raw materials in combination with a growing global population and more prosperity simply means that the pressure on the ocean will increase. For this reason some respondents to the questionnaire believed that activities such as deep sea mining – potentially harmful – cannot be avoided, although in that case we should do our utmost to keep the impact of these activities on the ecosystem as small as possible. The question is whether that is feasible.

Maximum exploitation, leaving the ocean be or find the middle way? Technology will certainly enable the ocean to contribute in 2050 to the sustainable supply of food, raw materials and energy. Chapter 5 shows that it can be done and also how it should be done. Chapter 6 will address the question how the ocean can contribute to the dealing with the effects of climate change. It is expected that the solution may be found in global governance (Chapter 7), but this will not be easy. Mankind still has a long way to go before we reach a potential final goal: Ocean City (Chapter 8).





## CHAPTER 5.

### SUPPLY OF NATURAL RESOURCES

If mankind succeeds in finding the middle between leaving the ocean alone and unregulated exploitation (Chapter 4) the ocean will in 2050 be our ally. The smart application of sustainable technology and improved knowledge of the ocean system will help us to make optimal use of the ecosystem services of the ocean. Indeed, our use of the ocean for the supply of natural resources will even contribute to the ocean's health, because we will have found ways to keep the system undisturbed.

How will technology help to bring about the sustainable supply of food, raw materials and energy? This chapter describes some concrete ideas on future applications. Some of these ideas can be realised in the near future (and some already have), albeit at a small scale, and will by 2050 be mature enough for large-scale application, whereas others – wild ideas – will only be drawn up by this time.

#### The ocean as a food source

The ocean is full of food, but the population growth, the effects of climate change and the lack of space forces us to find new food production locations. It is expected that in the future we will be making more intensive use of the ocean, but in a different way than today. In the sustainable future described in this book 'hunting and gathering' may have given way to ocean farms by 2050. In order to limit the influence on the environment to a minimum, these farms are to have closed production cycles. By 2050 fishing boats using trawls will have become a thing of the past, since fish will be lured to specific 'catch locations'. The ocean may even help us to cultivate fresh water crops. This is perfectly possible using transparent underwater tanks equipped with condensation systems.

*'The ocean as a nursery for food.'* [participant workshop]

### *Food from the bottom of the food chain*

In a sustainable future, organisms from the bottom of the food chain will play an increasingly important role in food production, also in the ocean. Their position in the food chain means they have a minimum impact on the environment. Besides, by filtering the water they help to clean it. There will be large-scale cultivation of algae and seaweed to serve as a basis for end products such as plankton burgers. Genetic modification may give algae new characteristics (e.g. in taste or structure), which will make it easier to transform them into different types of food such as crispy crackers or exciting drinks. Filter feeders<sup>6</sup> such as mussels and oysters are also ideal for cultivation.

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*'By 2050 the ocean will have become a large-scale production environment.'* [participant workshop]

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### *Ocean farm*

Large-scale fishing may be replaced or at least reduced by the cultivation of fish in closed systems, either on land, the sea or the ocean (at ocean farms). A closed cycle will be crucial. A sustainable future more or less prohibits feeding cultivated fish with fish from the wild (from outside the cycle), whereas waste should not be allowed to pollute the environment. One way to achieve this is combined cultivation, cultivating algae and seaweed and mussels and oysters in a single system. By customising the system and tuning it to the natural cycles it will be possible to produce food in a sustainable way. Systems such as these are also referred to as aquaponics. Sensor technology and robotics will ensure the right conditions for optimal production.

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<sup>6</sup> A filter feeder uses its gills or other specifically evolved organs to filter out plankton and other food floating in the water. (translated from nl.Wikipedia)



## A sea farm in the middle of the ocean?

by Willem Brandenburg, Wageningen UR

If we want a future with sufficient food and green raw materials for a green chemical industry we will have to think of large ocean farms to cultivate seaweed in a way that is Triple P\*. This effectively means that more than one function will be performed at the ocean farm, so not just seaweed for proteins and other crucial nutrients, but also sugars and specific carbohydrates for the green chemical industry. Carbon will have to be transformed into durable carbon fibres, which have characteristics that make them useful for construction. At the same time they will absorb CO<sub>2</sub> and NO<sub>x</sub> from the atmosphere, mitigating the effects of climate change. An ocean farm should be a large-scale enterprise, e.g. at least 5,000 square km on the Mid-Atlantic Ridge. The total length of this ridge could accommodate ca. twenty of such farms, held in place by GIS\*\* buoys and longlines. Depending on their location they may have a year-round harvest of seaweed. Precision agriculture techniques can be used to extract the dissolved greenhouse gases and phosphates from the water column and to deposit the sediment as accurately as possible close to the seaweed.

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\* Triple P: people, planet and profit in an ideal balance.

\*\* GIS: Geographic Information System.



*'In 2050 we will be on our way towards sustainable production at sea (on the ocean) and the cycle will be closed, something that is not the case yet.'* [participant workshop]

### *Selective fishing*

Fish is one of the important sources of proteins from the ocean. It will still be there in the future, although the way we will be fishing will have changed. It is conceivable that 'hunting and gathering' fish will be replaced by technology (e.g. using pheromones or sound) that will lure the fish to specific catch locations. In the future it may even be possible to train cultivated fish to swim to a specific catch location after receiving a stimulus (e.g. with the use of pingers – appliances producing sound). This catching method is called ocean ranching. The advantage is that large-scale transport by fishing boats is no longer necessary, which means that CO<sub>2</sub> emission will go down. Disturbance of the seabed by trawls will also be a thing of the past. It is then possible to leave the protected nature reserves alone, which will have a favourable effect on fish stocks.

Another potential fishing method will be using underwater drones or ROVs in combination with transponders<sup>7</sup>. The young fish will be tagged, so that it becomes possible to track them and have robots catch them at some later stage. The drones will more or less be 'vacuuming' the fish and take them to a mother ship.

### *Land crops in transparent underwater tanks*

Perhaps in the future freshwater and saltwater cultivation may be done in transparent underwater tanks in the open ocean. The moderate conditions (few temperature changes) will be a large advantage for the production process. Sensor technology will monitor conditions and autonomous robots will do the harvest at the right moment. Fresh water for irrigation comes from a condensation system.

### *Closed cycle*

Natural systems need balance, which is why it is important that the nutrient cycle is closed. At present this is often not the case. For instance, agricultural areas are exposed to rain, causing large quantities of nitrogen and

<sup>7</sup> Combination of transmitter and responder: appliance that responds to a received message.

## The future is closer than you think...

### Gardening at the bottom of the sea

Italy is already conducting experiments with underwater cultivation. This underwater farm consists of air balloons with planters that are anchored to the seabed. The basil actually looks delicious, and it turns out the lettuce, garlic and radish thrive equally well in the underwater greenhouse. In time this small-scale experiment should result in large-scale underwater fields. [Steijaert, 2015]

phosphates to be washed into the ocean. The phosphate stock, however, runs out and it is possible to use algae and seaweed to reclaim it from the ocean, meaning that the phosphates could be used again. Besides the nutrient cycle, all future activities should aim at closed cycles.

### Remark

What will our fishing fleet look like in the future? Some participants in this study believe that it will still exist in 2050. In the rich nations of the West fleets will be optimised, but the Middle East and Asia will still be lagging behind for decades when it comes to smart fishing.

*How will the ocean be able to contribute to the food supply in 2050? In the workshop on this question these keywords came up.*

---

**FOOD SOURCES** aim for primary production   deep sea  
 organisms (shrimp)   black smokers for specific products  
 micro-organisms for production   tubers and roots   seabed  
 organisms (wurms)   sea vegetables   plankton   sea fruit  
 spore elements   sea mammals   jellyfish   octopus  
**IMPROVE** use bycatch for fodder   use entire  
 organism   balanced fishing   **TECHNOLOGY**  
 artificial upwelling   aquaculture combined with storage  
 and logistics   open ocean farming in transparent  
 tanks   floating fields   artificial meat   salty cultivation  
**APPLICATION** plankton burger

---

## Extraction of raw materials

The ocean contains practically all elements from the periodic table. Apart from these elements – sometimes scarce and valuable – it also offers construction materials such as sand, gravel and stone. Some organisms from the ocean contain silicate, pigment and calcium. The question is not



### MENU

Restaurant Ocean View  
Delicacies from the ocean in 2050

Kitchen open from 11:00 – 22:00

#### Entree

- 🍴 Brine-cured salad of samphire  
and grilled tube worms
- 🍴 Creamy jellyfish soup with saffron

#### Main course

- 🍴 Real steak\* with deliciously salty potato  
mash and mixed ocean vegetables
- 🍴 Spicy plankton burger with French  
fries and colourful salad
- 🍴 Paella of sea fruit\*\* and cultivated  
fish (tastes like wild fish!)

#### Dessert

- 🍴 Chocolate mousse\*\*\* with salty caramel  
(from our own desalination plant)
- 🍴 Basil ice\*\* with strawberries

\* From real cow (no artificial meat)  
raised on sustainable seaweed

\*\* From certified ocean farm

\*\*\* No animal ingredients



whether the ocean can supply these materials, but whether it is economically and ecologically viable and desirable to extract them. Especially deep sea mining at the bottom of the ocean was by the participants in this study viewed as undesirable. The areas involved are often untouched yet and it is unknown what will be the impact of industrial interference in these systems. The sustainable vision of 2050 therefore places a focus on large-scale extraction of plastics and other waste products, the harvest of minerals from organisms and low-impact deep sea mining.

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*'The ocean is a gold mine.'* [participant workshop]

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### *Plastics as raw material*

The ocean is full of (micro)plastics, which is detrimental to the organisms and ecosystem, but may also serve as a valuable raw material that can be used for a wide variety of products. The retrieval of plastic from the ocean is actually a win-win situation. It solves a problem while simultaneously providing us with raw material. Although this is already happening at a small scale, in the future it may well become commonplace. A potential method to extract microplastics would be the development of a material that binds microplastics, thus increasing its volume. The increased size will make it easier to filter it from the water. Apart from plastic the ocean contains many more waste products that would allow recycling or could be used to generate energy through fermentation or incineration.





## The future is closer than you think...



### **The Ocean Cleanup**

The Dutchman Boyan Slat devised a method – The Ocean Cleanup – to clear away the plastic soup from the ocean. Together with an international team of scientists and engineers he developed a technology that enables the large-scale extraction of plastic using a gigantic network of floating barriers. Instead of using ships to collect the plastic this technology is based on passive collection by using the ocean flow. In this way the plastic will be concentrated at a single location after which it can be transported ashore. In 2020 the system should be operational. The technology will be tested first in the North Sea and then become operational near the coast of Tsushima, Japan. [The Ocean Cleanup.com]

### *Bio-mineralisation*

Bio-mineralisation is a process in which organisms create minerals in a structured manner. The best known example is the shell of shellfish, but the mechanism also applies to other types of minerals. Nearly all minerals can be extracted using organisms, from uranium to iron oxides, meaning that there is always a way to make an oxide or any other deposit settle on a biological structure. So instead of extracting minerals from the bottom of the ocean it is possible to use organisms to do it for us. In 2015 this technique was used for the next generation of lithium batteries. Seaweed can also be used to extract scarce minerals without disturbing the seabed. The waste product can be used to produce food or to serve as biofuel.

### *Low-impact deep sea mining*

In order to achieve the lowest possible impact on the ecosystem deep sea mining structures should make as little contact as possible with the seabed and with natural structures such as hydrothermal sources. This is the only

way to avoid damage to the bottom and upwelling of sediment. Robotics allow precision extraction of manganese nodules without disturbing the seabed or bycatch of other organisms or matter. Although this will have less impact on the seabed environment this would still amount to the extraction of an exhaustible material, meaning that the process is not sustainable. Hydrothermal sources and the surrounding areas are rich in materials (e.g. sulphides, but also silver and gold) and organisms able to produce interesting proteins in extreme conditions. It is expected that these organisms and their DNA will increasingly be used for the development of e.g. pharmaceutical products. Research in this area is already underway on the island of Curaçao.

### *Local processing of raw materials*

In the future the raw materials extracted from the ocean will be increasingly processed on the ocean itself, one example being the Malayan state oil company Petronas, which will introduce the first floating plant to liquify gas for transport at sea near the source. This will eliminate the need for pipelines, because the gas will be transferred directly to cooled tankers. There are plans for ca. twenty of these plants worldwide.

#### **Sea Salt City**

##### **What can we do with all the salt left after desalination for drinking water?**

What can we do with all the salt left after desalination for drinking water? We could actually use the water of the ocean to build desert cities. First, the ocean water becomes drinking water for consumption and cultivation. The rest of the salty water will evaporate so that only salt remains. In combination with starch from algae this makes a very useful building material, as was demonstrated at Delft University of Technology. [ING, 2015a]

### *Remark*

The growing global population and increased prosperity boost the demand for raw materials. But what if 11 billion people all want to have a mobile phone and a golden ring? Where do we get the raw materials? There is also the issue of the geopolitical situation. Many raw materials come from unstable areas, meaning that companies and governments prefer to extract them from the ocean themselves rather than being dependent on suppliers

unable to deliver at all times. The question is therefore not whether we will be extracting more raw materials from the ocean in the future, but how we should go about it without inflicting damage to the ecosystem.

*How can the ocean contribute to the supply of raw materials in 2050?  
In the workshop on this question these keywords came up.*

METALS manganese cobalt copper iron ore nickel lithium  
SALT potassium sodium BUILDING  
MATERIAL sand gravel stone silt RECYCLING  
plastic wood rope water production combined with living at sea  
BIOMASS plants seaweed calcium from  
phytoplankton silicate pigment reclaiming  
nutrients (phosphate) DNA BLACK  
SMOKERS heat pharmaceutical industry cosmetics  
CHALLENGES pressure make use of extreme conditions  
AIR bird faeces rain WATER COLUMN all  
solvable substances closed cycles TRANSPORT TO  
SURFACE windmills pumps on seabed counterweight  
cleaner separation techniques for water salt and metals

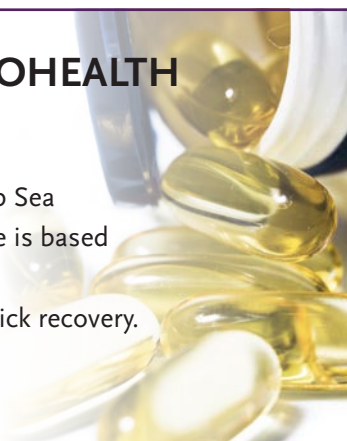
– Advertisement from the future –

## Deep sea medicine: PYROHEALTH

Troubled by an inflamed bladder?

Try **PYROHEALTH** from our new Deep Sea Medicine line. This powerful medicine is based on the unique DNA structures of the *Pyrococcus furiosus*\* to guarantee a quick recovery.

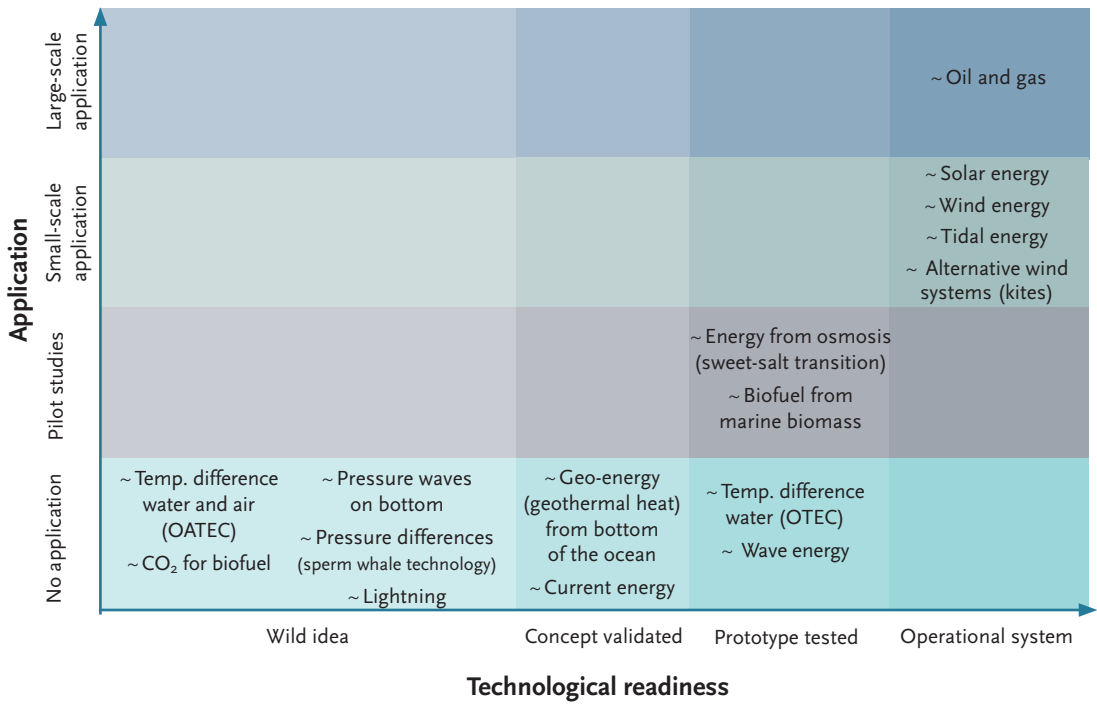
\**Pyrococcus furiosus* is a bacteria living at the bottom of the ocean near hydrothermal sources.



## Energy supply

The ocean is perfectly suited to extract energy from, and there are many ways to do it, including solar energy, OTEC (Ocean Thermal Energy Conversion), tidal energy, flow energy and wind energy (Figure below). The participants in this study believe that people will in 2050 no longer be extracting oil and gas– or at least hardly – and that by then the world has completed the transition to renewable energy. The extraction of energy from the ocean is a big topic in the offshore industry. Looking at the time horizon of 2050 experts believe that this will happen sooner rather than later and certainly sooner than the production of food or the extraction of raw materials. Besides the extraction of energy will continuity of the energy supply, the combination of the production and use of energy and energy transport also play a role in a sustainable future.

### Types of energy extraction from the ocean



## The future is closer than you think...



### **Adaptive wave plant**

Researchers from the University of Groningen demonstrated with a scale model of a wave power plant – the Ocean Grazer – that it is able to absorb up to 95 percent of the energy of a passing wave. The total yield of the platform is probably somewhere between 60 and 70 percent, which is higher than comparable systems. Scale models and theoretical models have shown that the system works, so it may become reality in the near future. [Fransen, 2015]

### *Combining the extraction and use of energy*

When energy is extracted from the ocean at the location where the energy is being used, the need for expensive transport is eliminated. Floating windmills can be used to drive deep sea pumps to pump up the raw materials. It would also be possible to build ocean farms at the location where the energy is actually produced.

### *Combinations with other types of use*

There are more ways to combine the extraction of energy with other forms of use, e.g. food production. OTEC (Ocean Thermal Energy Conversion) is a technology that makes use of the temperature differences in ocean water. To achieve this, cold ocean water is pumped up from the deep. This water is rich in nutrients and biomass, both highly suitable for food production on the ocean. At the same time OTEC is an artificial variant of upwelling.

Another opportunity for combination use are the underwater turbines generating power from the flow or the tide. Filters in front of the turbines prevent animals and waste from getting trapped. The waste and the organic material filtered from the water can be used to produce food, fuel or raw material.

## **An Ocean Full of Opportunities**



### *Continuity of energy supply*

For a reliable energy supply continuity is crucial, since electrical appliances are sensitive to fluctuations in power. One way to counter this is to spread the risk by generating wind, solar and flow energy at the same time, thus increasing the chance that enough power will be generated at any given moment. Sensor and information technology will adjust the energy production in such a way that all production locations cooperate to an optimum. To manage fluctuations large-scale networks are necessary. An additional option would be a smart system that stores the energy when production is high, to release it when production is low. This would be a solution for wind energy, where fluctuations in power generation are still a large obstacle. On windy days the surplus energy could be stored by pumping up water inside the windmill itself. Or a so-called energy island could pump the water from a reservoir in case of surplus energy. In case of a power shortage the water will flow back through a turbine to generate power. In the present circumstances – large-scale extraction of wind energy at sea and on the ocean – this technique could contribute to a higher production.

The varying supply of renewable energy sources – especially solar and wind energy – implies that in the future the capacity for temporary storage will become more important, both short-term (day-night) and seasonal storage. Batteries are most suitable for short-term storage. They are designed for efficient loading and unloading within a short period of time. With stationary applications the price and the possibility to load and unload the



battery for a long period of time and very frequently will be decisive. For transport, however, the energy density and volume will be an. Short-term storage will mostly be decentral, whereas seasonal storage is best achieved by converting electricity into gas, e.g. hydrogen or ammonia. This storage will be mainly done at central locations where the supply of sustainable electricity is high, e.g. where the cables of the wind turbines at sea reach the shore. Stations nearby can convert the surplus production into gas which is then stored onsite so the power plant will be able to produce extra electricity in winter.

*'The ocean is the biggest battery we have.'* [participant workshop].

The high pressure at the bottom of the ocean can also be used to store energy. In Norway researchers are working on a concept based on underwater tanks containing a turbine than can rotate in two directions. It costs energy to empty the tanks, but to generate energy the only thing people have to do is to open the tanks and let the water flow full force through the turbine. [newenergyandfuel.com]

### *Large-scale energy transport*

If in 2050 insufficient energy is produced on land or if it is cheaper or easier to do this at sea, this creates the need for ways to transport the energy to shore. The production of energy may exceed the local need, and a somewhat wild idea is to use geo-engineering for transport. The energy is used to create a hurricane and/or a tsunami that will be directed to shore. There it will be converted to energy again by large installations, but whether this can be done in a controlled manner, is a question that can not be answered yet. It would, however, be a way to transport massive amounts of energy without the need for infrastructure at the bottom of the ocean.

## The transition to renewable energy sources from the ocean is not a matter of course

by Ewald Breunese, Shell

The ocean is full of energy: below the seabed, in the water itself, at the surface and above (sun and wind). The available ocean surface and the volume of the ocean do not stand in the way of space-consuming energy production. If we look at the current renewable energy sources – sun, wind, waves and tides – the material intensity (and in turn also capital intensity) is high compared to the conventional sources, oil and gas. Local energy production on the ocean may become attractive if the costs of transport are low. The expectation that in 2050 there will be no longer – or hardly – any extraction of oil and gas is from a technological and economic perspective unfounded because of the high energy density of oil and gas compared to the new sources. However, in view of the greenhouse gases and climate change people should in 2050 have the right to expect that the extraction of oil and gas will by then be combined with the capture, reuse and storage of CO<sub>2</sub>. The types of energy that are at present under development will probably not play a role on a global scale yet. For these new technologies to reach maturity, 2050 is much to close.

Energy extracted through osmosis or from the tides can only be done in coastal areas, which fall outside the scope of this book.

What will happen to the enormous oil and gas infrastructure on (and in) the ocean? Adaptation? Transformation? Disassembly? Actually, it is already possible to ship an offshore platform back to shore. The Allseas Pioneering Spirit is able to pick up and transport discarded platforms. It is also possible to use deserted platforms to house wind parks, while waiting for new technology to arrive.

*How can the ocean contribute to the supply of energy in 2050?  
In the workshop on this question these keywords came up.*

ENERGY TRANSPORT flows hurricanes satellites clouds  
iceberg tsunami TECHNOLOGY ship with solar batteries  
following the sun underwater turbines solar cells at sea  
storage and continuous supply sweet-salt energy at artificial islands  
solar-powered cleaning robots nuclear energy pressure pumps  
optimisation through IT sensor technology and model research  
SOURCES OF ENERGY pressure differences (sperm whale  
technology) fish movements black smokers wave energy  
tidal energy plastic biomass sun flows using gravity to  
sail lightning tsunami hurricanes temperature differences  
salt gradients Lorentz force biofuel discards OTEC  
geothermal energy biofuel from CO<sub>2</sub> friction of tectonic  
plates gas hydrates offshore kite energy biofuels waves  
temperature differences tides solar energy biomass (algae)

### What if... energy will be free in 2050?

Will the use of the ocean increase once energy no longer forms a limitation to transport? Or will we be in a position to leave the ocean alone, because free energy enables unlimited production of fresh water through desalination of ocean water, helping us to make deserts fertile again?

### *System integration*

In workshops of this explorative futures study it was seen that especially the combination of the various functions of the ocean is an important factor in the economically viable use of the resources from the ocean. The combining of functions also contributes to sustainability (see 'Energy supply' on p. 79). These combined functions are described in the vision of the future in Chapter 8.







## CHAPTER 6.

# DEALING WITH THE EFFECTS OF CLIMATE CHANGE

There are various ways to deal with the effects of climate change:

1. We can try to fight one of the causes of climate change by reducing the emission of greenhouse gases (climate mitigation);
2. We can adapt to the effects of climate change (climate adaptation); and
3. We can intervene in the thermoregulation and weather systems of our planet through geo-engineering.

This chapter describes ideas on how the ocean of the future can contribute to the dealing with the effects of climate change. The issues involved in climate change are often closely connected with the theme discussed in the previous chapter.

The international climate debate seems to more or less ignore the ocean, so it is high time to focus on the close relationship between the ocean and our climate.

*‘Securing the ecosystem and the exclusively sustainable use of the ocean require instant action to combat what is presently viewed as the cause of climate change, as well as the impact it has.’ [respondent online questionnaire]*

### Climate mitigation

The participants in this study stated that in 2050 we will have made the full transition to renewable energy, which will help to reduce the emission of greenhouse gases. Large-scale production of renewable energy from the ocean is possible (Chapter 5). By rendering ocean transport more sustainable, reducing our CO<sub>2</sub> footprint in food production and closing the production chains by 2050 the open ocean will be able to reduce (or even eliminate) CO<sub>2</sub> emission caused by human activity.

## Sustainable energy

Sustainable energy is viewed as the solution for the reduction of our CO<sub>2</sub> emission through CO<sub>2</sub>-neutral energy supply. It will also stimulate economic development based on the almost unlimited supply of energy on the ocean. There are many forms of renewable energy from the ocean. The participants in this study believe that the technological innovations required to achieve this may move forward quickly. For this reason in 2050 the ocean – by supplying sustainable energy – will certainly contribute to the reduction of the global emission of greenhouse gases.

*'I think that the ships of the future will sail autonomously (without crews) in long lines.'* [participant workshop]

## Reducing transport emissions

Ocean transport puts pressure on the environment. It is also expensive. Global trade, fishing and the extraction of raw materials require vast amounts of ocean transport. Although shipping is less harmful for the environment than airfreight, climate-neutral ocean logistics would effectively help to reduce the emission of greenhouse gases. Without this we will never achieve sustainable use of the ocean. One way to reduce emissions is by looking at propulsion systems. The ships of the future will be propelled by alternative fuels or wind and solar energy instead of the present – highly polluting – fuels. Reducing ocean transport emissions can also be achieved by making smart use of ocean and tidal flows and sailing as much as possible with the wind. One could also think of some 'hitchhiking system' in which all activities at sea (also those by researchers) make better use of existing transport movements, more or less like carpooling or 'Uber on the ocean'<sup>8</sup>. Another option to limit transport would be to process raw materials and food on the ocean, meaning that less transport of bulk loads of raw materials will be required.

<sup>8</sup> Uber is an online transportation network company, which operates an app that allows consumers to submit a trip request which is then routed to Uber drivers who use their own cars. [Wikipedia]



### *Food production*

Eating organisms at the bottom of the food chain (algae, seaweed and filter feeders) instead of beef will help reduce the footprint of food production on climate change (see Chapter 5).

### *Closed production cycles*

Transforming waste into raw material means that less natural resources are lost and fewer raw materials have to be extracted from the ocean (requiring much energy). This principle can be applied by collecting the waste in the ocean and use it as raw material or to produce energy. Food production units such as ocean farms should also be based on closed production cycles, which is in line with the ideas set out in Chapter 5.

### **Climate adaptation**

Participants in this study stated that it may be possible to limit climate change for some time, but that it cannot be stopped. Apart from countering the cause we should therefore also think about how we can adapt to the effects of climate change. This adaptation strategy will require more flexibility from people, especially when it comes to living and agriculture. It would e.g. imply that people would have to live in areas with the most favourable climate and no longer invest in keeping locations habitable under extreme conditions. The ocean may become a living environment as well.

The Netherlands is doing a great deal about climate adaptation (e.g. the Room for the River project and climate-adaptive cities. [[www.ruimtelijkeadaptatie.nl/en](http://www.ruimtelijkeadaptatie.nl/en)]) This applies to both the technical level (modelling, etc.) and governance. How do you design adaptive decision-making? How do you include various functions in the design? At present measures are confined to land, but in the future they may also be applied to climate adaptation on the open ocean.

### *The ocean as a source of food and drinking water*

Drought as the result of climate change may result in decreased food production and extreme living conditions in some areas of the world. The ocean can contribute to the solution through food production (see Chapter 5). If energy becomes very cheap or even free in the future, the desalination of ocean water can be applied to the production of drinking water. The vast quantities of water that will become available can be used to refertilise arid land areas through irrigation.

### *Living on the ocean*

If living on land as a result of climate change and/or population growth becomes problematic, the ocean could offer living space on floating islands for mobile and flexible living and working. These islands would be able to adapt to changing conditions by simply relocating to areas with more favourable climates. Chapter 8 describes life in a city floating on the ocean. See also the intermezzo on p. 94.

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*'If you look at population growth I think the ocean offers the best chance for a substantial expansion of our living space.'*

[participant workshop]

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**The first to go under ...**

The social effects of climate change may be dramatic. Already the inhabitants of small island states are witnessing the effect of the sea level rise caused by climate change. The Marshall Islands in the Pacific are now only a few metres above sea level and will disappear in the foreseeable future, turning the inhabitants into the first climate change refugees in the modern age. What will their fate be? What will it do to their culture? Will they be the first to live in floating cities on the ocean?

**Active intervention in the climate through geo-engineering**

The close relationship between the ocean and our climate implies that large-scale intervention in the marine system through geo-engineering could have a large impact on our climate. This could, for example, be done by improving the ocean's CO<sub>2</sub> buffer function or by making changes in the ocean current for a positive effect. The participants in this study were extremely critical of such interventions, which in the long run will only offer a temporary solution.

### *CO<sub>2</sub> storage*

The ocean can be used for climate mitigation by strengthening its buffer function for CO<sub>2</sub>. It has a huge capacity for storing CO<sub>2</sub>, which can be enhanced yet through iron fertilisation to stimulate the growth of algae. But this is only a temporary solution, because in the end the CO<sub>2</sub> will still end up in the atmosphere. Other methods to capture CO<sub>2</sub> include the transformation into carbon fibres (see p. 71) or using bacteria to capture CO<sub>2</sub> in ethylene, the main ingredient of plastic.

~~~~~  
*'Help, the world is drowning!' [participant workshop]*  
 ~~~~~

### *Intervention in the ocean current*

Another large scale action could be intervention in the ocean current for a direct change in the weather and the climate. This way the thermoregulation function of ocean currents can be adjusted to enable the ocean to absorb extra warmth at specific locations. This method could be combined with the generation of current energy.

### *Remark*

In the future geo-engineering may offer possibilities, although nearly all participants in this study expressed their concern. Large-scale tampering with the system – of which we do not know nearly enough – involves the risk of a potentially large and unpredictable impact on the environment and its natural processes.

**What if ... we view climate change as an opportunity instead of a threat?**

What would be a smart use of higher temperatures, changing precipitation and windspeeds in the open ocean?

## A future climate summit

What will future climate negotiations look like? Which concerns will be expressed by the inhabitants of the floating ocean cities? How will the debate proceed between NGO Bluepeace – an influential NGO that is passionately against any tampering with the natural system – and Blue Technology Industries – the branch organisation for technology companies specialised in geo-engineering? Will the threats uttered by the president of Zandalonia – a desert nation finding itself on the edge of destruction due to climate change – put the future of the entire global population at risk?






For this study a climate summit was simulated, a role play in which the above and other issues were laid on the negotiation table, and issuing the climate treaty of the future:

### Ocean city 2050 Climate Treaty

Undersigned declare that starting 2050 the following measures will go into effect in order to utilise the ocean for dealing with the effects of climate change:

- Measure 1) Free exchange of services, knowledge and techniques.
- Measure 2) Room for double technology in the ocean.
- Measure 3) Fundamental rights and obligations for all citizens, including free traffic of people and goods between the land and the ocean.

Ocean City, 10 November 2050

|                                                                                                                          |                                                                                                                                            |                                                                                                         |
|--------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------|
| <i>President Zandalonia</i><br>       | <i>President Fortilia</i><br>                           | <i>BluePeace</i><br> |
| <i>Blue Technology Industries</i><br> | <i>Citizens First</i><br>on behalf of all citizens?<br> |                                                                                                         |

\* Double technology is technology that serves multiple aims and always contributes to society and/or the natural ecosystem.

INTERMEZZO

# The ocean as living environment

If in the future we actually decide to go and live on the ocean there are several issues we will have to consider beforehand. Why do we need the ocean as a place to live? What will be the consequences? What does living on the ocean mean from a legal perspective? Will the ocean become a new, independent state? Who has the ownership? And who decides who gets to live on the ocean?

## The future is closer than you think



Living on the ocean isn't as far as you think. There are plans to build a floating city in the Sargasso Sea. According to the Seasteading Institute\*, building could start in 2020. This think tank believes that floating cities will help to solve issues such as food security, health, cleaner atmosphere, recovery of the ocean, living in harmony with nature, sustainable living and peaceful society, in short, the eight moral imperatives. According to the Seasteading Institute, oceans offer room to live, food and renewable energy. Due to the fact that these independent, floating cities are able to move elsewhere and rearrange themselves, the governments of these cities will have to do their best to keep their inhabitants satisfied, otherwise they will simply move elsewhere. The feasibility study was carried out by the Dutch design firm Deltasync. The first concept consists of 11 modules and is able to house 225-300 inhabitants. The costs are estimated at US\$ 167 million.

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\* The Seasteading Institute is a non-profit think tank aiming to inspire people to think of new forms of living on and at the water.





### Living underwater?

In the future it may become possible to live underwater due to the developments of a new material able to absorb oxygen from the water and release it in the underwater environment. This very promising material was developed by a team from the University of South-Denmark. The main component of the material is cobalt, which acts similar to artificial hemoglobin, being able to bind, store and transport oxygen.

### If more and more people will go and live on the ocean, what will happen to the land?

If living on the ocean becomes commonplace, living on land will become special. To the ocean dwellers land will become a tourist attraction for terrestrial nature tourism, old school car driving on deserted roads and looking at cultural-historic landmarks. Land will also remain a source for land-specific raw materials and delicacies, including agricultural crops that are salt-intolerant but still very popular.





## CHAPTER 7.

# SUSTAINABLE MANAGEMENT AND USE OF THE OCEAN

The previous chapters described ideas on how technology may help to make sustainable use of the ocean for food, raw materials and energy, as well as ideas on dealing with the effects of climate change. The sustainable use of the ocean is not as obvious as one may think. The ocean is like a candy store; everybody is trying to take a pick, which carries the risk of overexploitation (Tragedy of the commons). Active management and enforcement are needed to skim the ocean instead of robbing it empty (i.e. just use the interest of the savings account, not the capital itself) in order to support the marine ecosystem and maybe even improve it. Management and enforcement can only be the result of international agreements. This chapter describes how management and sustainable use of the ocean should be settled in a legal sense, that is, from an economic and politic point of view.

According to the participants of the workshops, the answer to the question of how we should organise the use and management of the ocean in 2050 to guarantee a sustainable future is: global agreements on what we want to – and can – extract from the ocean. This will make the management and use of the ocean an international responsibility which transcends borders and interests. Some experts stated that the revenues of the ocean should be available to all the people on this planet, since the ocean is a common good. According to them, in 2050 the international policy should be aimed at a global, fair distribution of raw materials. Governance of the ocean should be aimed at the management of the entire ocean, taking into account the 3D structure of the ocean; the bottom, water column, surface and air above the ocean. These should all be included in a global policy that lays down rules for the management and use of the ocean. Fragmentation of the oceanic space – as happened on land through allotment– and the fragmentation of management and policy are undesirable.

But how can we organise this international approach to sustainable management and policy in 2050? This question generated multiple ideas. A selection of these ideas per category, with examples clarifying their potential mutual connection and a diagram (Figure on page 102) may be found below. For most participants in this study the solution would be a strong international body that imposes responsible use through international legislation and guidelines, as well as strict enforcement. People also expected an increasing role for citizens in knowledge gain (citizen science) and participation (crowd governance).

### *Remark*

Establishing an international body that enforces sustainable use of the ocean will not be easy in the short term. Also, it remains to be seen whether this body will be in a position to prevent unsustainable exploitation. Not all nations have the same opinion on the importance of preserving nature or sustainable use. There is also a political aspect: some nations might view such plans as Western colonialism once again. For more on this subject, see the Reflection.

## **Implementing policy**

### *Rules and regulations*

In 2050 consensus has led to global regulations for the management and use of the ocean. This is a framework legislation providing enough liberty for regional implementation. The legislation describes the effect, not the means, and there is room for adaptation based on monitoring results (adaptive legislation). Legislation should be binding. History has shown that if nations do not feel bound by international agreements nothing constructive happens.

### *Monitoring*

We will need global monitoring to ensure that the influence of the various uses on the ocean environment is known. The monitoring data of governments, research institutes and users will be publicly available in 2050. One obvious challenge for monitoring is the sheer size of the ocean, although new sensor and information technology will help to solve this.

## Enforcement

Enforcement can be achieved through technology, by which drones, ships, aircraft and satellites are deployed. Nations which violate the rules should be named and shamed as well as pay a fine. The open data allows interest groups and political institutions to act when users of the ocean ignore the rules. Social and other media will be used to mobilise the public to help monitor the use of the ocean.

*'In 2050 more knowledge will be available to keep the oceans and the environment healthy.'* [participant workshop]

## Knowledge development

A sustainable policy presupposes expertise. At this moment we know too little about the effects of industrial activities on the oceanic environment to determine whether these are sustainable or not. In view of the limited means and capacity of research institutes, a collaboration with trade and industry is inevitable. Companies can provide their data themselves or contribute to a fund for knowledge development. New knowledge is one thing, but we should also make better use of the existing knowledge, such as the knowledge of indigeneous tribes. These tribes often know much more about living in harmony with nature. Tribes on islands or on the coast can teach us all about things like sustainable fishing.

## Collaboration

International policy and enforcement will require collaboration between nations and sectors. Consortiums of developed and developing countries should work on the exchange of knowledge and techniques.

*'We have to deal with the ocean in a sustainable manner. But this is relatively unexplored territory: we do not know how the ecosystems of the open ocean will respond to increased human influence. If we want to explore and use the ocean in a way that is as sustainable as possible, we will need close international (global) collaborations, negotiations, etc.'*  
[respondent questionnaire]

## Role of the citizen

### Awareness

The first step to enable an active citizen role in sustainable use, management and enforcement is more awareness of the ocean as the source of life on earth. There are various means to stimulate this; from education, serious gaming and social media to 'sea artists'. Technology will also play an important part in creating awareness, e.g. underwater cameras broadcasting the livestream 'follow the codfish family'.

*'It is my hope that in 2050 the ocean will be "closer to home" for many people.'* [participant workshop]

### Citizen science

In the future citizens may be called upon more frequently to collect data and to analyse data made available by the government, research institutes and trade and industry.



### Crowd governance

Social and other media will be used to mobilise citizens to monitor the use of the ocean. They will have access to the open data made available by the government, research institutes and trade and industry.



## International bodies

For international governance two structures are conceivable, namely top-down institutions (such as the UN) and bottom-up networks (such as island councils). The future international institutions mentioned below all work top-down:

### *Open Ocean Council*

An international body in which all nations participate. It is responsible for global policy, management and enforcement of the open ocean, shaping a community of users and countries that will account for their own actions. This international council could e.g. allot concessions that are open to anyone, meaning that each nation shares in the cost of and income from the open ocean. One potential obstacle is the disadvantage of poor countries. This can be resolved by actively supporting these countries.

### *Ocean Bank*

This world bank will stimulate the sustainable and responsible use of the ocean by only investing in sustainable projects related to the management and use of the ocean. This bank is comparable to the current Triodosbank.

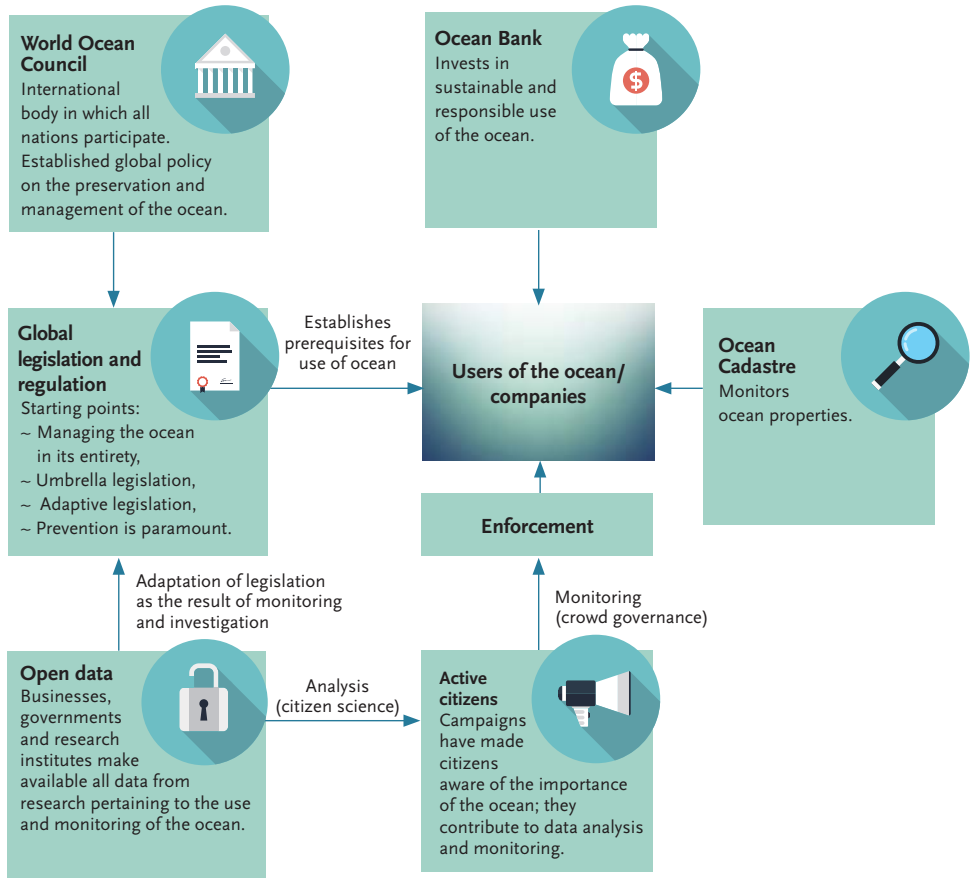
### *Ocean Cadastre*

Once we will be using the ocean more intensively, ownership issues pertaining to the ocean and its natural resources will become more important. The Ocean Cadastre will monitor the distribution of exploitation rights. One of the advantages of ownership is that it generally leads to more responsibility and involvement, which benefits sustainability. The Ocean Cadastre can play a vital role in a world in which the ocean is still a common good.

### *The ocean as a state*

Tragedy of the commons is about the management and use of a common good. One way to solve the issue would be to turn the ocean into a separate state, formed by the inhabitants of the floating cities. They will have the

*'Buy the land and first build a house. Then people can live in it. In other words, we should all work together to establish the political and economic structure, including the "right of ownership", although this is a very complex issue. [...] Otherwise we may be looking at another Wild West, but this time at sea.'* [participant workshop]



### *Governance of the open ocean in 2050?*

right to use raw materials, energy and food from the ocean. The surplus can be exported to land.

### **Governance of the open ocean in 2050**

The elements of governance described above are all interconnected. The Figure above shows how the international organisation of ocean management and policy could be realised. In order to keep this example simple not all elements described above have been included in the diagram. All kinds of combinations are possible. What does the ideal governance structure look like? Top-down or bottom-up? Do we leave everything to the free market or do we need strict legislation? Or perhaps a combination of both?

The Open Ocean Council will be responsible for global policy. The international framework legislation will establish what kind of use of the ocean

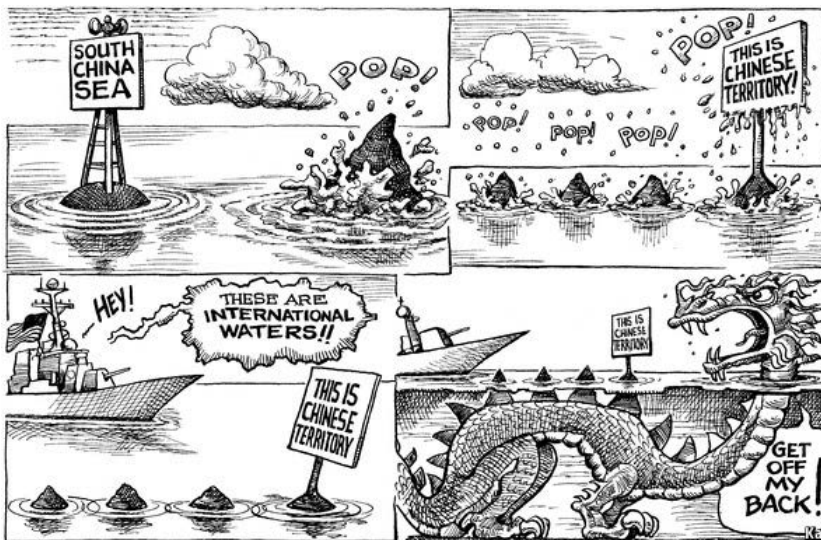
### **An Ocean Full of Opportunities**

is permitted. Nations and companies can claim concessions to extract raw materials, catch fish, etc., as long as this is done within the confinements of the law. The concessions that are given out are entered into the Ocean Cadastre. Whether specific types of use are permitted – i.e. are viewed as sustainable – will also depend on international investigation and monitoring results, which are based on the analysis of large amounts of open data, smartly managed by an international IT structure. The citizens are committed and contribute to the analysis. They will take action together with NGOs if users do not stick to the rules. Users are also stimulated to make responsible use of the ocean through investments by the Ocean Bank.

### Remark

The growing demand for raw materials and the increased technological possibilities will spur countries to stake more claims on the natural resources of the ocean. In the future this may lead to large-scale military conflicts.

Already nations are claiming parts of the ocean by building artificial islands (See cartoon below) to expand their Exclusive Economic Zone (EEZ). In the case of China this is accompanied by an increased military presence, inciting other nations such as the Philippines, US and Vietnam to do the same. In May 2015 the Malaysian minister of Defence Hishammuddin Hussein stated: “This situation has the potential to lead to one of the deadliest conflicts of our time, if not in world history.” [Elsevier, 2015]



Expansion of chinees territory in the Southern Chinese Sea. [www.economist.com]

*How can we organise governance of the open ocean in 2050 in such a way as to enable the preservation and sustainable management of the ocean? In the workshop on this question these keywords came up.*

---

**LEGISLATION** Consensus World Ocean Council Ocean Cadastre  
 Umbrella legislation Regional conventions Global legislation

**IMPLEMENTATION/USE** Developed and developing countries  
 Certification Consortiums Funds for knowledge development  
 Cooperation Standards Citizen science Ocean Bank  
 Open data Awareness

**ENCOURAGING SUSTAINABLE USE** Output in line with input  
 NGO Common interest Pressure from the market

**POWER SHIFT** Democratic check on the military  
 Ocean as a state International committee Crowd governance  
 Power Economic diplomacy Power to the people

**ENFORCEMENT** Naming and shaming Enforcement by ships,  
 aircraft, satellites International Surveillance Fair distribution

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## CHAPTER 8.

### VISIONS OF THE FUTURE: OCEAN CITY



**The ideas on how the ocean can contribute to the sustainable solution of several great societal challenges (as described in the previous chapters) all come together in this vision of the future, the thriving community of Ocean City.**

Welcome to Ocean City, the capital of Oceanea and the pride of all its inhabitants. As a result of climate change, technological developments and the growth of the population, some fifteen years ago the first floating cities were built, mostly of recyclable material such as empty oil barrels. The first floating islands were still small and close to the coast, but that has changed. Technology has allowed Ocean City to grow into a mostly self-sufficient high-tech environment. The hexagonal modular design was a fantastic breakthrough at the time. It is now the model for most ocean cities that are being built.

The core values of Ocean City are self-sufficiency and sustainability. Its inhabitants strive for full independence, and are already almost self-sufficient in energy, food and raw materials. Smart collaboration between the various sectors has created a highly efficient closed system in which food, raw materials and energy are produced in harmony with nature.

Although there are many ways to extract energy from the ocean, Ocean City aims at wave energy, OTEC and solar energy. The city holds a patent on some new technology that enables the breakwater structures outside the city to produce energy from wave movements. In the city itself solar cells have been installed in each building. In this respect Ocean City is still very much like the cities on land, where decentralized energy supply has been common for about twenty years now.



The ocean farms are based on the combined cultivation of algae and seaweed alongside oysters and mussels. Tube worms have become a local delicacy. They are harvested by deep sea robots and transported to the town using floating windmills. Inside the circle of breakwater structures surrounding the town there are various catch locations for wild fish. In accordance with international arrangements of the Open Ocean Council – of which Ocean City is an autonomous member – the only fish that can be caught at the moment are codfish and saithe. Ocean City is happy to comply, because all inhabitants are aware of the importance of healthy fish stocks in the ocean.

After the Great Manus Disaster<sup>9</sup> the Open Ocean Council banned deep sea mining for the large-scale extraction of minerals from the bottom of the ocean. Small-scale exploitation of minerals and deep sea organisms is allowed as long as there are no alternative sources, and only if it is authorised by the Deep Sea Mining Authority. This is done by two home-based companies, working closely together with the pharmaceutical and chemical industries that are leading in marine biotech. Their pharmaceutical products and product enhancers are sold worldwide.

<sup>9</sup> The Great Manus Disaster was a large environmental disaster in 2028 as the result of the large-scale sulphide and silver extraction at the Central Manus Basin off the coast of Papua New Guinea.

Also booming is the processing of plastics and other recyclable material from the ocean into raw material for 4D printers, to produce items that can alter their shape under specific conditions. The inhabitants of Ocean City have a hard time understanding why people once thought this valuable material to be waste, and tossed it right into the sea. However, it has provided Ocean City with a lucrative business, so one should actually thank the people who polluted the ocean in the past.

The inhabitants of Ocean City make an effort to waste as little as possible. Glass, metal and paper are all recycled using cutting-edge technology<sup>10</sup>, such as nanorecycle robots. Plasma gassing<sup>11</sup> is used to convert organic material into electricity. The people from this city all care for the ocean, and some help to regularly monitor the publicly available data on the state of the ocean. Others are lobbying to make users of the ocean aware of the advantages of sustainable use, taking action when users ignore international agreements.

In short, Ocean City is a thriving community, where human well-being goes hand in hand with a healthy ocean. And all this has been made possible through smart use of technology, citizen commitment and international collaboration. Like it? You can now subscribe to the new underwater city district currently being built.

### Some facts on Ocean City

- ~ Largest floating city on the planet
- ~ Fully self-sufficient in all sectors
- ~ Citizen commitment is the norm
- ~ Always the latest technology, e.g. in aquaculture

<sup>10</sup> Cutting-edge technology is the most advanced technology.

<sup>11</sup> Process in which high temperatures are used to turn waste into its basic components.







In this publication we have reflected on the question of how the ocean in 2050 can contribute to the supply of natural resources and the dealing with the effect of climate change, the prerequisite being that the ocean is being preserved and only used in a sustainable way. The participants in this explorative futures study have all presented their thoughts on how renewable energy can be extracted from the ocean in the future, what it means to live on the ocean, which international agreements will be needed, etc. This book offers a view on the possible futures of the ocean by presenting suggestions that came up during the workshops, the interviews and the online questionnaires. Hopefully these glimpses of the future have made you think about the functions of the open ocean, but also about its vulnerability and the question of how technology and governance can be deployed to use the ocean's ecosystem services in a responsible (sustainable) manner.

### Guidelines for action

Apart from sketching the potential future developments this study also provides insight into what can be done right now to achieve sustainable use of the ocean in 2050, starting from the perspective of technology and governance. This way we will be able to recognise threats and seize opportunities in time, and prepare for the future. So what actions can be taken? Below you will find a number of guidelines.

A **national debate** on the sustainable use of the ocean, and work on the implementation of **international policy** is needed. The development of **new knowledge** will allow the Netherlands to highlight its **international profile** as a seat of knowledge. Knowledge development and **smart combinations** will enable system integration, which is expected to be the most profitable course of action. The time to start relevant **pilots** is *now*.

These are the guidelines for action:

### *National debate*

The visions of the future presented in this book are aimed at starting a national debate. To seize the opportunities offered by the innovation of sustainable technologies, and come to an agreement on the future policy on the use of the ocean, it is necessary to start the discussion with all relevant parties, government, trade and industry, research institutes and NGOs. The first question to be answered is: “What is already being done?” An overview of current developments in the various sectors and (scientific) disciplines is needed. The subsequent question is: “What do we want to do with the ocean, maximum or sustainable exploitation?” And subsequently: “How can we realise our common ambition in this domain?” At present, research institutes, trade and industry and the government are fragmented. To make progress, organisations need to join forces, starting with a debate.

### *Smart combinations*

In the workshops the general feeling was that most profit can be gained by linking up in projects the various types of use made of the ocean (food, raw materials and energy). The combination of these functions requires system integration. Right now many projects are running separately from each other. There is work to do on the standardisation of systems and on improved collaboration between existing and future projects.

### *New knowledge*

To enable the sustainable use of the ocean, knowledge development is necessary. There is still little known about the ocean itself, let alone about the impact of human activities on the ecosystem. Extended research is needed to establish which technologies and which uses of the ocean are sustainable. At present only large companies with large budgets can develop the technological equipment for the future exploitation of areas that could not be reached in the past. By contrast, the research institutes that should be charting the natural system at the bottom of the ocean and determine what will be the impact of human activities generally have limited financial means. This means that the research that should be providing the framework for international policy is lagging behind. In the ideal situation this research should determine which economic activities – and their impact on the ecosystem – fit within the common ambition and which does not.

It is therefore essential to not just develop technology for use in the ocean, but to also invest in research, monitoring and knowledge management. In order to keep knowledge of the ocean at an adequate level it is important to keep investing in education. Equally important is the notion that the debate on how to deal with the ocean is very much needed.

Knowledge development hinges on collaboration. Much of this knowledge is present in the Netherlands, albeit very fragmented. Taking the knowledge of the ocean and the technology required to use it in a sustainable manner to the next level calls for national collaboration. Following Norway, which established the Ocean Space Centre to this effect, the Netherlands should be thinking of its own Ocean Technology Centre

### *International knowledge profile*

Our knowledge of the ocean, technology, sustainability and governance allows the Netherlands to present an international knowledge profile, e.g. in green shipping, the cultivation of salty crops and the generation of renewable energy. We can share this knowledge with other nations, meaning that both national and international collaborations will be needed, including joint research and projects with trade and industry. After all, sustainable use of the ocean is an international issue.

### *International policy*

International policy is fragmented as well. There are dozens of international organisations and agreements on the use and management of the open ocean. This carries the risk that these institutions will all be working independently of each other. A clear and univocal international policy on the ocean would improve things. This can of course not be achieved from one day to the next. The first thing is, again, to start the debate.

### *Pilots*

To make the ideas on the sustainable use of the open ocean regarding both technology and governance come true, pilot studies are needed now, and initiate the international (and national) debate on sustainable policy and international agreements. The North Sea provides the perfect breeding ground for experiments with new techniques and governance for sustainable use of the sea to obtain food, raw materials and energy. Subsequently, the pilots can be upscaled to ocean level, something that, nationally and

internationally, is already happening in renewable energy and food production at sea. Not all applications that are suitable for the coast and on the North Sea can, however, be implemented on the open ocean (e.g. tidal energy technology). The concept, for instance, of the self-sufficient living units on the ocean could be tried out first on islands serving as a field lab. This is already being done on the island of Aruba, where sustainable innovations in energy and water are being tested.

The debate on the role of the ocean in countering the grand challenges as well as the role of technology should not be limited to the question whether a specific idea on future use of the ocean will become reality or not. We rather prefer to sketch in this publication the possible perspectives, showing how the ocean can contribute to these challenges. This publication contains many ideas on various types of use and management of the ocean in 2050. Each separate idea could in fact form the starting point of further research on technological feasibility, ecological desirability and social probability.

## Conclusion

The ocean has much to offer us, and is certainly able to contribute to a solution for the grand social challenges in the upcoming 35 years (and after). But if we want to profit from its ecosystem services in the long term – supply of food, raw materials, energy, and dealing with the effects of climate change – we must make sure that the ocean stays healthy. For this reason the use of the ocean should be aimed at the sustainable use of its products and services, while preserving the ecosystem. We can achieve this by learning from nature and developing smart technological solutions based on our knowledge on the ecosystem. Solid international arrangements are required on policy, monitoring and enforcement for global surveillance of the responsible use of the natural resources provided by the ocean. The Netherlands has the knowledge of sustainable technology to deal with these challenges, and the experience in governance for sustainable management. National and international dialogue and the formation of collaborative efforts will allow us to take a first step in the direction of a durable, blue future. The ocean belongs to us all. If we manage to collaborate, there will be an ocean of opportunities waiting for us.







## APPENDIX 1.

### ABBREVIATIONS AND GLOSSARY

#### Abbreviations

EC: European Commission

EEZ: Exclusive Economic Zone

EU: European Union

GMO: Genetically Modified Organism

GOOS: Global Ocean Observing System

GSC: Grand Societal Challenge

IODE: International Oceanographic Data and Information Exchange

MEDIN: Marine Environment Data and Information Network

NGO: Non-Governmental Organisation

OTEC: Ocean Thermal Energy Conversion

ROV: Remotely Operated Vehicle

STT: Netherlands Study Centre for Technology Trends

UN: United Nations

UNCED: United Nations Conference on Environment and Development

#### Glossary

**Biomining:** Formation of minerals by organisms in a structured manner, e.g. the shell of a shellfish. The mechanism may be applied to extract various types of minerals from the ocean.

**Climate adaptation:** Adaptation to the effects of climate change.

**Climate mitigation:** Active intervention in the climate, e.g. through geo-engineering.

**Deep sea mining:** Extraction of raw materials from the bottom of the ocean.

**Ecosystem service:** The social benefits extracted from ecosystems.

**Geo-engineering:** Large-scale manipulation of natural systems.

**Governance:** Decision-making, implementation and evaluation at various levels (international, national, regional and municipal) in collaboration and solid communication between the state, the market and society.

**Grand Societal Challenges:** Challenges related to a combination of large public and private interests, seen as very relevant for future economic growth and connected with important social and/or environmental problems.

**Hydrothermal source:** Underwater geysers spouting extremely hot water of sometimes 350°C full of (poisonous) minerals. These minerals turn the water black, which is why they are called black smokers. The conditions in these environments are so extreme that the organisms living there (especially micro-organisms) are called extremophiles.

**Iron fertilisation:** The adding of iron to the surface water of the ocean to stimulate phyto plankton. The increased biological production helps to stimulate the absorption of CO<sub>2</sub> from the atmosphere. [Wikipedia.org]

**Klimaatadaptatie:** Aanpassing aan de gevolgen van klimaatverandering.

**Ocean Thermal Energy Conversion (OTEC):** Technology using the temperature differences in ocean water by pumping up cold water from the deep.

**Olivine weathering:** The structure of olivine (a common natural material extracted in mines and excavations) makes it very sensitive to weathering. During the weathering process CO<sub>2</sub> is extracted from the atmosphere and capture in the form of bicarbonate.

**Open Ocean:** Part of the ocean outside the jurisdiction of national EEZs (Exclusive Economic Zones). This is the area far from the coast, outside the continental shelf, including the air above, the water surface, the water column and the bottom of the ocean.

**Sustainability:** 'Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.' [UN, 1987] Applied to the ocean, it is about the extraction of natural resources without exhausting them. Also, the activities needed to extract natural resources must not result in negative disturbances of the marine ecosystem, thus endangering the ecosystem services it supplies.

**Upwelling:** Natural or artificial upward flow of cold and eutrophic water from the deep ocean.

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## APPENDIX 3.

### STRUCTURE OF THIS EXPLORATIVE FUTURES STUDY

This study was carried out by a project team collaborating with a large number of experts and interested parties, for which see Appendix 4. Participants.

#### **Study of the literature and expert interviews**

Expert interviews and a study of the literature determined the theme of this concise study, namely the open ocean as the solution for grand societal challenges, and to be more specific, the current grand societal challenges and technological developments directly connected with the open ocean.

#### **Online questionnaire**

An online questionnaire was used to involve a wide range of experts, stakeholders and futurologists in this study. In the first round they were asked which grand societal challenges the ocean could help to solve. Based on the results two major societal challenges were selected: supply of natural resources and the dealing with the effects of climate change, the prerequisite being the preservation and sustainable use of the ocean.

In the second round an inventory was made of the characteristics and ecosystem services of the open ocean playing a major role in dealing with these challenges, including the threats involved. The respondents were also asked which technologies they expected to be applied for the exploration, exploitation and monitoring of the ocean in 2050, followed by the question which of these technologies would be the most desirable. The results of the second round served as input for the visions of the future of the use of the ocean in 2050.

#### **Visions of the future by students**

In the module 'Project Future' the students in Industrial Design Engineering at the Haagse Hogeschool focused on the ocean as a future living environment and a source of energy. Their dream scenario was captured in a vision of the future, including a roadmap.

## Workshops

In workshops with experts, stakeholders and futurologists visions of the future were created, sketching the role of the ocean in the supply of natural resources and the dealing with the effects of climate change, provided that the ocean is preserved and used in a sustainable manner. The focus was placed on technology and governance. Five workshops were organised. Participants came from trade and industry, the government, NGOs, research institutes, etc. The results of the workshops formed the basis for the visions of the future presented in this book.

## Meer informatie?

If you want to know more about the research question, reports on the questionnaires, student reports and the workshops, please visit the STT website: <http://stt.nl/publicatie/stt-83-een-oceaan-vol-mogelijkheden/>.

Here you can also download a digital copy of this publication.

## APPENDIX 4.

### PARTICIPANTS

#### Acknowledgements

The results of this study were made possible by the participation of a large number of people and organisations. Without their commitment and scientific, reflective or creative input we would never have reached our goal. We like to thank all participants for that. They are listed here in Appendix 4.

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*Mentor*

**Laura Stevens**

## **Participants in the online questionnaire**

The online questionnaires were carried out on the basis of anonymity.

## Participants in the workshops



### *North Sea workshop 'Sustainable management of the North Sea: today and in the future'*

#### **2 October 2015, Vlissingen (Flushing, the Netherlands)**

**Asjes Jacob**, IMARES

**Backer Joost**, Rijkswaterstaat

**Baptist Martin**, Wageningen University

**Berg Frank van den**, TNO

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**Bruens Ankie**, Deltares

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**Hest, Floris van**, Stichting De Noordzee

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**Mienis, Furo**, Cioz

**Perk, Luitze**, WaterProof B.V.

**Poppema, Daan**

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**Smaal, Aad**, Wageningen University

**Steenbrink, Sander**, Boskalis

**Stuijzand, Suzanne**, Rijkswaterstaat

**Svoboda, Annemarie**, Rijkswaterstaat

**Vlak, Kees**, Rijkswaterstaat

## *1st workshop round*

Question: 'How can we use the open ocean in a sustainable way for the extraction and/or production of natural resources in 2050?'

### **28 October 2015, The Hague**

**Dam-Mieras, Rietje van**, Zeeland-net/ Unesco

**Dekker, Jos**, Utrecht University

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**Jansen, Albert E.**, Water Innovation Consulting

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**Lanters, Ronald**, Wing

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**Neven, Ine**, Province of South Holland

**Nijman, Job**, Fugro

**Schaetzle, Olivier**, Wetsus

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**Stigter, Henko de**, NIOZ

**Tatman, Sharon**, Deltares

**Verwoest, Timo**, MARIN

**Zwieten, Paul van**, Wageningen University

### **30 October 2015, The Hague**

**Abspoel, Lodewijk**, Ministry of Infrastructure and the Environment

**Brandenburg, Willem**, Wageningen University

**Drontmann, Philip**, Arcadis

**Duijne, Freija van**, Ministry of Economic Affairs

**Gotjé, Wouter**, Arcadis

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**Römgens, Ben**, DNV GL

**Smit, Marck**, NIOZ

**Verwegen, Martijn**, NWO

**Vrees, Leo de**, Rijkswaterstaat/ Ministry of Infrastructure and the Environment

## *2nd workshop round*

Question: 'How can the ocean contribute to dealing with (the effects of) climate change?'

### **10 November 2015, The Hague**

**Assen, Chris van**, World Wide Fund for Nature

**Dielissen, Esther**

**Duin, Patrick van der**, Delft University of Technology

**Gotjé, Wouter**, Arcadis

**Lanters, Ronald**, Wing

**Neven, Ine**, Province of South Holland

**Nijman, Job**, Fugro

**Reimert, Zinzi**, TNO

**Teal, Lorna**, IMARES WUR

**Valk, der**, Wageningen UR

**Yurtseven, Suleyman**, DS Engineering

### **13 November 2015, The Hague**

**Bontenbal, Marike**, Unesco

**Dielissen, Esther**

**Doorn, Hanneke van**, Royal Netherlands Academy of Arts and Sciences

**'t Hart, Pieter**, Maritiem Kenniscentrum

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### *Project team*

- ~ **Marie-Pauline van Voorst tot Voorst**, project leader orientational stage and 1<sup>st</sup> deepening phase, coach 2<sup>nd</sup> deepening phase and publication.
- ~ **Stephanie Ijff**, project leader 2nd deepening phase and publication.
- ~ **Annette Potting, Japke Schreuders, Leandra Huijbregts**, project support.
- ~ **Esther Dielissen** (external), **Dhoya Snijders** and **Ellen Willemse**, support during workshop phase. **Ellen Willemse** also supported the final editing.



## APPENDIX 5.

### ABOUT STT



The Netherlands Study Centre for Technology Trends (STT) is a non-profit knowledge institute. The board consists of over sixty representatives from the top of Dutch government, trade and industry, research institutes and NGOs.

For 48 years the core activity of the Netherlands Study Centre for Technology Trends (STT) has been the organisation of broad, long-term futures studies and horizon scans on the edge of technology and society. Enthusiastic stakeholders are provided with a space to cocreate visions of the future of technology and society.

These futures studies aim to inspire to visioning and agendas for the future, but they also lead to research programmes, networks, institutes and projects.

Apart from this, the STT Academy embarks on various other activities, including the financing of Special Chairs, method development, master-classes and the management of the Netwerk Toekomstverkenningen – a platform for knowledge exchange – and Young STT.

Information on STT, its activities and product may be found at [www.stt.nl](http://www.stt.nl).

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## STT-publicaties

### **STT 82 Beter?! Toekomstbeelden van technologie in de zorg**

Redactie Ellen Willemse, m.m.v. Lisa van Bodegom, 2015  
(ISBN 978 94 913 97 110)

### **STT 81 Van autonome robots tot zilte aardappels. Toekomstverkenning naar de invloed van technologische ontwikkelingen op de agri- & foodsector tot 2050. English pdf available**

Silke de Wilde met Ellen Willemse, Raoul Blankensteijn en Koen Donker van Heel, 2015 (ISBN 978 94 913 9709 7)

### **STT 80 Horizonscan 2050, Anders kijken naar de toekomst. English pdf available**

Jacintha Scheerder, Rene Hoogerwerf, Silke de Wilde, 2014  
(ISBN 978 94 91397 07 3)

### **STT 79 Aspirine op je brood. Voeding en geneesmiddelen in de toekomst**

Ellen Willemse, 2013 (ISBN 978 94 91397 05 9)

### **STT 78 Het vervoer van morgen begint vandaag. (Ver)voer tot nadenken en doen. Pdf comprehensive English summary available**

Marie-Pauline van Voorst tot Voorst en Rene Hoogerwerf, 2013 (ISBN 978 94 91397 06 6)

### **STT 77 Samen Slimmer. Hoe de 'wisdom of crowds' onze samenleving zal veranderen**

Redactie: Maurits Kreijveld, 2012  
(ISBN 978 94913970 2 8)

### **STT 76 Serious Gaming (serie van 3 publicaties).**

**Vergezichten op de mogelijkheden.**

**Play On: Serious Gaming voor de nieuwe generatie senioren.**

**Serious Games, Playful Business: Toekomstbeelden van de spelende organisatie.**

Jacco van Uden, 2011 (ISBN 978 90 809613 0 2)

### **STT 75 Futures of Technology in Africa (English)**

Jasper Grosskurth, 2010 (ISBN 978 90 809613 7 1)

### **STT 74 Bargaining Norms – Arguing Standards (English)**

Edited by Judith Schueler, Andreas Fickers, Anique Hommels, 2008  
(ISBN 978 90 809613 4 0)

### **STT 73 Brain Visions. How the Brain Sciences. Could Change the Way We Eat, Learn, Communicate and Judge (English)**

Edited by Ira van Keulen, 2008 (ISBN 978 90 809613 6 4)

### **STT 72 Deus et Machina. De verwevenheid van technologie en religie**

Redactie: Michiel D.J. van Well, 2008 (ISBN 978 90 809613 5 7)



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## APPENDIX 6.

### ABOUT THE AUTHORS



**Stéphanie Ijff** Worked from September-December 2015 as interim project leader on the futures study of the ocean. She graduated in August 2015 at the University of Utrecht with an MSc in Environmental Biology and is now working at Deltares as junior researcher/consultant Marine and Coastal Management. Stéphanie's interest lies in finding natural solutions for challenges in the water sector, including water quality and flood control.



**Marie-Pauline van Voorst tot Voorst** has worked as a project leader at STT since 2010 in the project Super Intelligent Transport, and started the futures study An Ocean of Opportunities. In the closing phase of the latter study Marie-Pauline acted as coach. In 2011 she received an MA in Knowledge Technology at the University of Maastricht.

## APPENDIX 7.

### REFERENCES USED PHOTOGRAPHS AND IMAGES

Provided: p. 4

Haagse Hogeschool, project team 'New Atlantis – Sea city': p. 71 en 108

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The Ocean Cleanup: p. 76

The Seasteading Institute: p. 67 and 94.

[www.maritime-connector.com](http://www.maritime-connector.com): p. 89

[www.rug.nl](http://www.rug.nl): p. 80

See caption: p. 32, 54-55, 103

What will be the role of the ocean in 2050? Different scenarios are conceivable. Are we going to exploit the ocean to the max, leaving behind an uninhabitable, overfished and completely exhausted underwater world fought over by nations? Or will we opt for sustainable use, turning the ocean into our ally? An ally helping us feed the global population, and providing energy and raw materials without ever being exhausted? An ally that helps us deal with the effects of climate change?

This book aims to inspire the reader to reflect on the future of the ocean, while focusing on sustainability, technology and governance. Will robots be the driving force on floating ocean farms? Will wave energy illuminate our ocean cities? And what can we do to reach international agreements on the use of the ocean? Reflecting on these issues today will enable us to make conscious choices to protect and preserve tomorrow's ocean, and to use it in a sustainable way.

Let the creative and inventive ideas brought forward by the experts and stakeholders who participated in this STT futures study surprise you, and get acquainted with this ocean full of opportunities.

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