D.2.1– Market Assessment

Market assessment and Competitiveness of European supply industry

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THE OCEAN OF TOMORROW

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Abstract

The main objective of the NeXOS project is to develop new cost-effective, innovative and compact integrated multifunctional sensor systems which can be deployed from mobile and fixed ocean observing platforms. The sensor systems can be divided into ocean optics, ocean passive acoustics and EAF sensor systems (Ecosystem Approach to Fisheries management). Within the NeXOS project, WP2 aims to:

- Assess the economic viability of sensor system requirements and products;
- Develop industrialisation strategies for the projects where applicable.

These tasks are performed in close cooperation with WP1 of NeXOS and especially the work performed on identifying the social and economic requirements for sensor development.

The underlying report addresses the current market of marine environmental sensors and the competitive position of European sensor manufacturers therein.

Typically, marine sensors are used for one of the following particular aims:

- Legal aim: monitoring of the marine environment because legislation requires an actor to do so
- Industrial (commercial) aim: an economic operator uses sensors to monitor or steer its processes, as they are considered the most economically advantageous way to do so
- R&D aims: the use of sensors for the sake of science, without a pre-defined application in mind.

Although the driving force for the sensor market for many years has been the R&D marine environmental applications while industrial and legal uses where of lesser size, lately this balance has begun to shift in favour of demand related to industrial and legal purposes of using sensors. In the near and midterm future these two market areas are expected to grow even more and contribute the main volume of sensor sales.

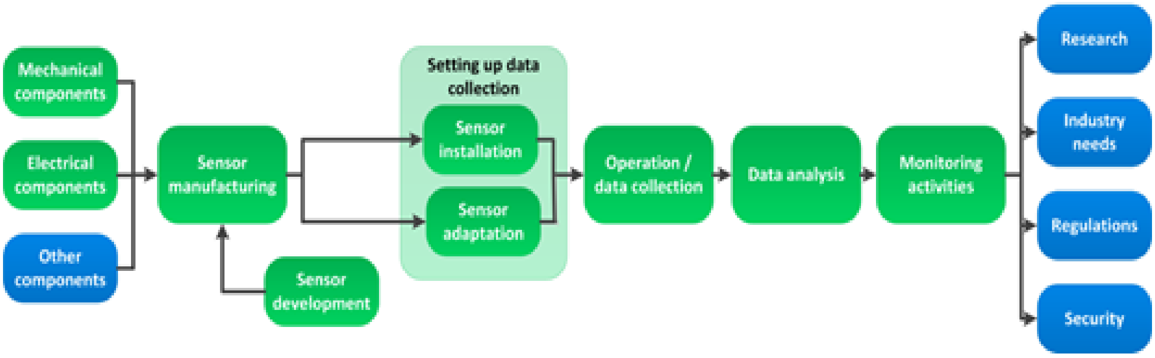
A list of 9 user groups (economic sectors) has been identified that use marine sensors for the purposes of their activities. Below table summarises them and their aims – which can be multiple. Also, the role that sensors play in each of these markets varies: in some sectors sensors are commonly applied (these are considered mature market for sensors) whereas in other markets the use of sensors is still in an infant stage. This also gives the basis for estimating the growth potential of sensor use in each of these markets, which has been assessed qualitatively in the two right-side columns in below table.

Aim / Market	R&D	Industrial / economic perspective	Legal	Role of sensors	
Sensor aim from the perspective of market sectors				today	In 2020
Monitoring of environmental quality	√	-	√	oo	ooo
Offshore oil & gas	√	√	√	oo	ooo
Industrial water quality measurements	?	√	√	oo	oo
Oceanographic research	√	√	√	oo	oo
Fisheries	√	√	√	o	oo
Aquaculture	√	√	√	o	oo
Ocean renewable energy	√	√	-	o	oo
Deep sea mining	√	√	-	-	ooo
Port security	√	√	√	o	ooo

The size of the global sensor market is not exactly known, but an estimation of the export market of instruments gives figures in the order of € 5.8 billion ($7.5 billion) in 2001, which has risen to € 12.4 billion ($16 billion) in 2011. However this estimation covers a market much wider than the sensor categories assessed within the NeXOS project. Further growth of the use of marine environmental sensors is driven by legal requirements (the Marine Strategy Framework Directive and subsequent monitoring guidance in particular), commercial considerations (sensors being adequate tools to monitor offshore operations and to be cost-effective systems of measurement and control) as well as ongoing research requirements (building on the globally increasing awareness of the importance of the ocean system to mankind).

Leading countries manufacturing sensors are found in the EU and North America, with five countries (USA, UK, Germany, France and Canada) jointly hosting about 62% of the market. The EU can take pride of currently being one of the leading actors holding a significant share of market (estimated at more than 35%). However when zooming in on particular sub-segments such as those addressed within NeXOS, such figure may vary widely and individual companies may have an estimated share of more than 50% in a particular field alone.

To assess the competitiveness of the European industry, the value chain for sensors was developed.



Depending on the market to be served, and in particular the maturity level of that market, the role of sensor manufacturers can vary from solely manufacturing the sensor and selling it to providing full services packages including installation, data collection, processing and analysis. Typically, business models evolve from full package services by manufacturers to specialised roles as the markets evolve from development towards growth and mature stages. When generalising across the various submarkets, typically four main stakeholder categories can be identified: sensor manufacturers, sensor developers, monitoring service providers, and users / clients. Each business strategy – and a handful of the possible combinations appear dominant – consists of a combined allocation of tasks across these four (or less of them if roles are combined).

NeXOS aims to provide added value through the development of new innovative sensors. Apart from the particular objectives, a number of general challenges have been identified that are relevant for all three sensor categories. They are summarised below.

Challenge	Optic	Passive acoustic	EAF
Power requirements	√	√	
Stability	√		
Standardisation*	√	√	√
Sensor interoperability	√	√	√
Fouling	√		√
Data transportation	√	√	
Gathering real-time data	√	√	

*Standardisation refers to the process of harmonising standards for sensors aiming on achieving interoperability but also on setting minimum requirement categories for their attributes so as to create sensor classes.

TABLE OF CONTENTS

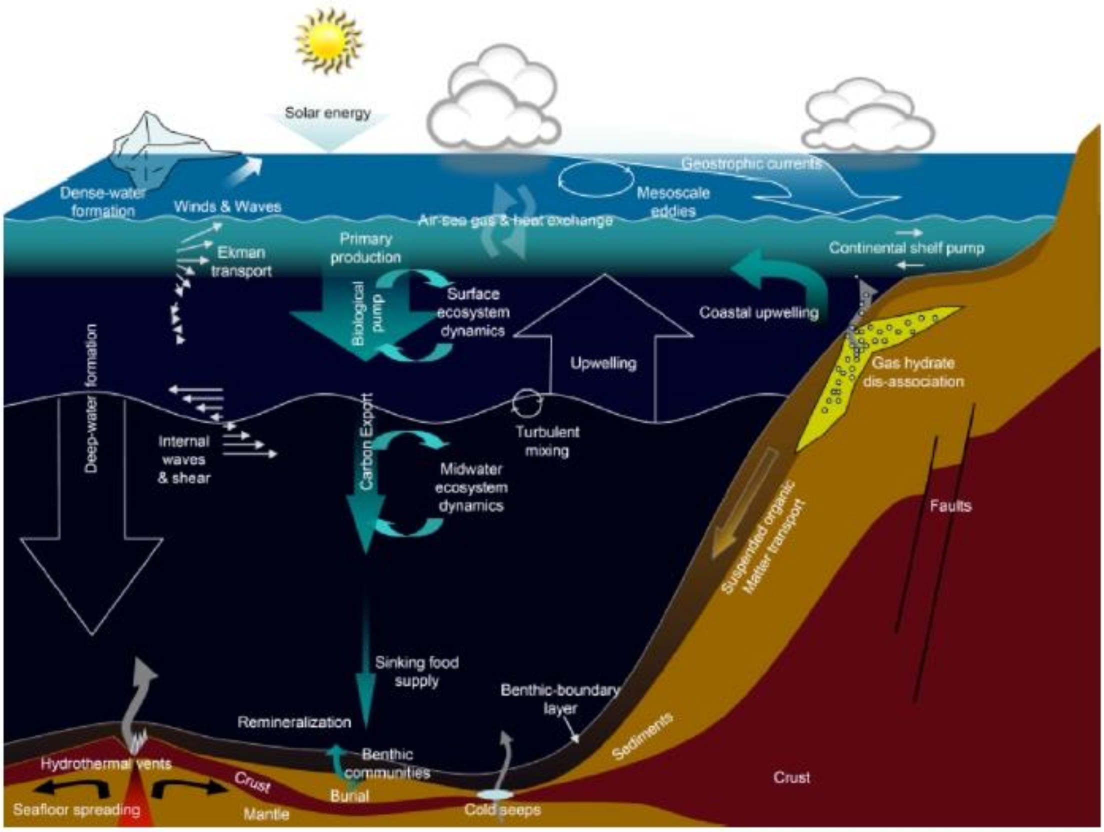
LIST OF FIGURES

1. INTRODUCTION

1.1 Background and objective

With a coastline of 89,000 km, along two oceans, four seas[1] and large overseas territories, Europe can be considered as a blue continent. Seas and oceans are important for human well-being and wealth, but they are also affected by human activities directly and indirectly[2]. Seas and oceans are complex systems and its balances can be disturbed easily. Small disruptions can have immense impacts on man, nature and climate, both positive and negative. A lot of different processes take place both above and under water as well as in the (sub-sea) earth. If one of these processes is interrupted, other processes may also be affected and cause impacts on its surroundings. The figure below shows a representation of major processes of nature occurring in the marine environment.

Figure 1-1: MAJOR PROCESSES IN THE MARINE ENVIRONMENT



Source: based on similar figures made by P. Cochonat, C. Berndt, Esonet Noe, and the US Ocean observatories initiative.

Because the marine environment is vital for human life, but is in itself very delicate, legislation to protect the marine environment in different aspects is imposed by the European Union (EU). Specific directives have been adopted to protect the Habitat, Fauna and Flora[3] and Birds[4]. Also the Water Framework Directive and the Marine Strategy Framework Directive have been adopted in order to

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1 The Atlantic and Artic Ocean, and the Baltic, North Sea, Mediterranean and Black Sea.

2 European Commission (2013)

3 Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora

4 Directive 2009/147/EC of the European Parliament and of the Council of 30 November 2009 on the conservation of wild birds

protect the seas and oceans of Europe[5].

These directives ask for monitoring the seas and ocean around us. They do not specify how the monitoring activities should be carried out, and so economic actors are free to choose the means to execute monitoring activities. One of the options is the use of marine sensors, which are able to gather large amounts of data and are able to operate for longer periods of time under water and away from the shore line. As it is expected that the size of monitoring activities will increase in the coming years, it is expected that the use of sensors will increase as well, as applying sensors will substantially save costs compared to other (more labour intensive) methods.

Although sensors have a large potential to assist in environmental monitoring several challenges need to be overcome, e.g. the lack of standardization, the high investment and maintenance costs of complete sensors systems, and the lack of interoperability. NeXOS is trying to tackle some of the challenges identified, by bringing together different economic actors that can together develop new solutions and innovations.

The main objective of the NeXOS project is to develop new cost-effective, innovative and compact integrated multifunctional sensor systems which can be deployed from mobile and fixed ocean observing platforms. The sensor systems can be divided into ocean optics, ocean passive acoustics and EAF[6] sensor systems. In addition downstream services for GOOS[7], GES[8] and CFP[9] will be developed. To achieve this objective the following ten specific objectives are formulated:

1. To develop a new, compact and cost-efficient multifunctional sensor system for optical measurements of several parameters, including contaminants such as hydrocarbons and other components of the carbon cycle.
2. To develop a new cost-efficient compact and integrated sensor system for passive acoustic measurements.
3. To develop a new low-cost sensor system for an ecosystem approach to fisheries management.
4. To develop and integrate a miniaturised smart sensor interface common to all new NeXOS sensor systems.
5. To develop and apply innovative sensor anti-fouling technologies.
6. To develop a common toolset for web-enabled and reconfigurable downstream services.
7. To assess and optimise the economic feasibility and viability of the new sensor developments including the manufacturing phase.
8. To demonstrate new developments in real operational scenarios.
9. To work with producer and user communities to upgrade requirements and provide a system which allows easier transition to manufacturing and operations.
10. To manage and coordinate the specific aims described above, and contribute to dissemination and outreach, to communicate the results and innovations of NeXOS.

The project is divided into eleven different Work Packages (WPs). Five of them, the technical WPs (WPs 3-7), focus on the development of the new sensor systems and tackling some of the more general challenges, e.g. anti-fouling. Other work packages are supportive to the technical work packages. The relationship between the different work packages and their execution in time are depicted in the following figure.

[5] Ministry of Ecology, Sustainable Development and Energy (2013)

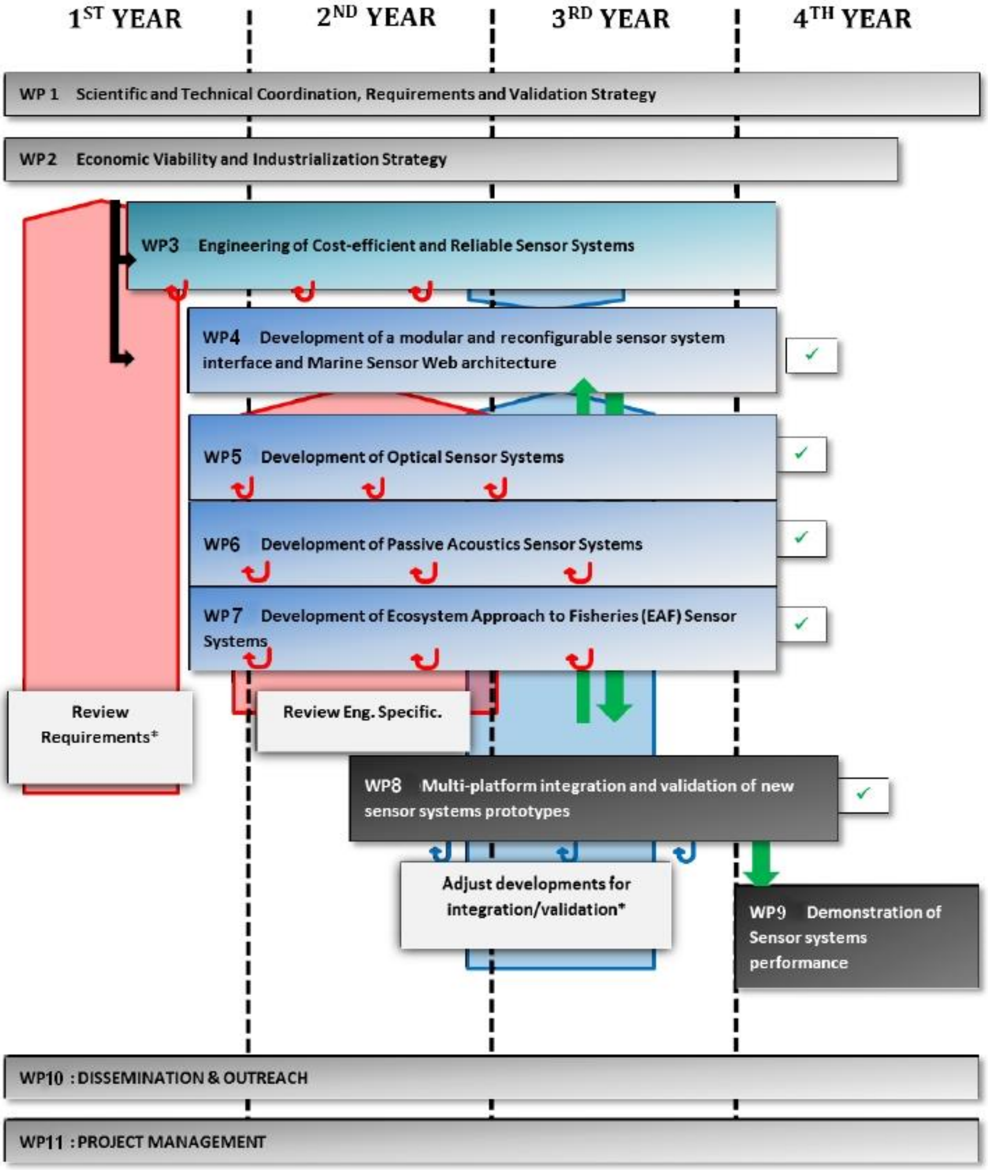
[6] Ecosystem Approach to Fisheries management

[7] The Global Ocean Observation System

[8] Good Environmental Status, a concept defined in the Marine Strategy Framework Directive including 11 indicators.

[9] Common Fisheries Policy

FIGURE 1-2: Set-up of NeXOS and the relationship between different WPs



Source: NeXOS Consortium

1.2 Aim and set-up of WP2

Work Package 2 (WP2) ‘Economic viability and industrialization strategy’ aims to analyse the market for sensor equipment and related services. The analysis takes into account the current demand for the equipment and services as well as the expected future demand. Besides a market analysis also the competitive position of European suppliers, both manufacturers (i.e. sensor equipment) and services providers (i.e. related services), in the global industry is considered, and possible business strategies for implementing new sensor products and services are developed. Therefore, WP2 consists of two main objectives:

- Assess the economic viability of sensor system requirements and products;
- Develop industrialisation strategies for the projects where applicable.

In order to analyse the main objectives of WP2 five tasks have been formulated, covering:

1. The assessment of the current market for environmental monitoring services and equipment (task 2.1);

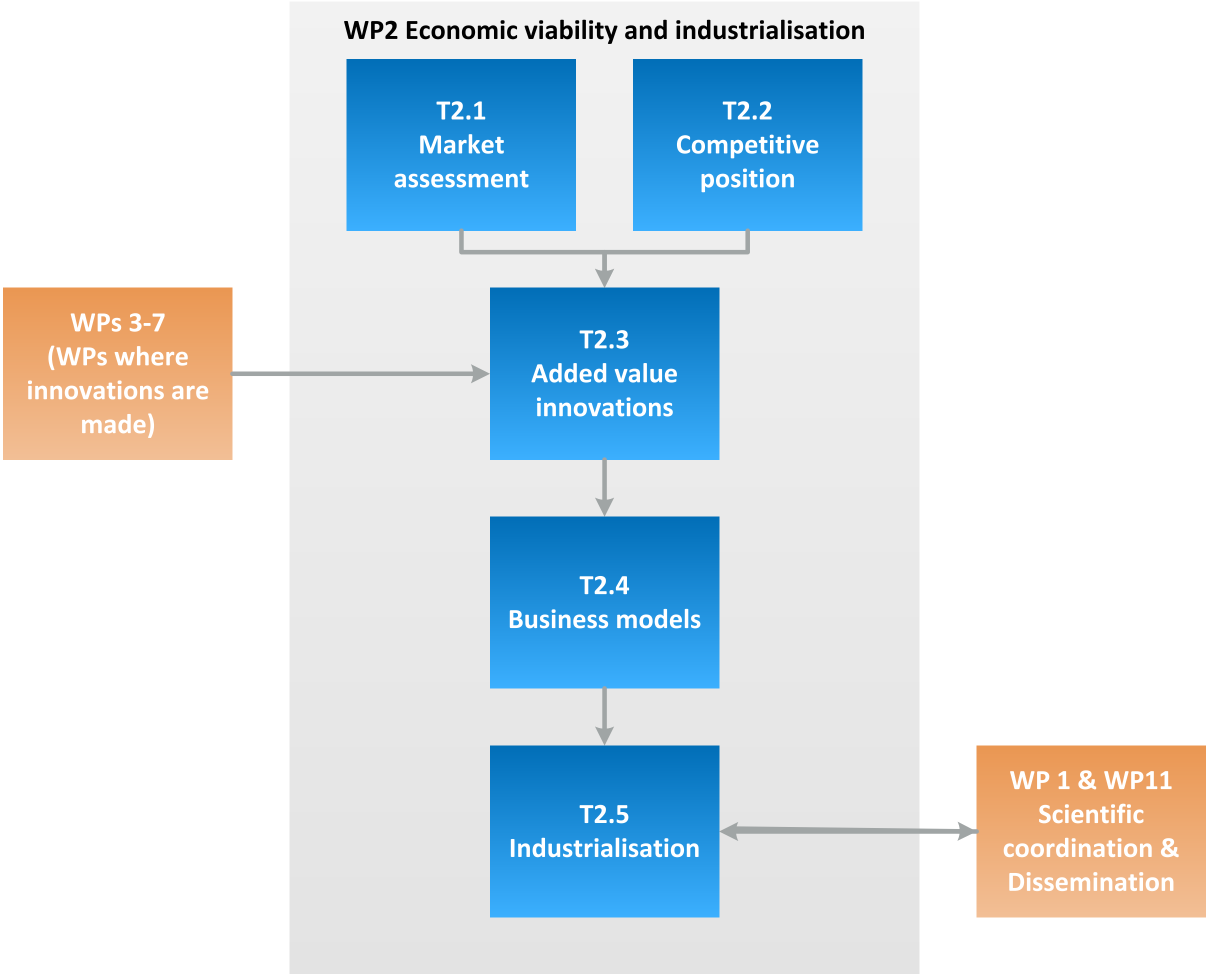
2. The assessment of the competitive position of European suppliers (task 2.2);
3. The constitution and initiation of the work of the Subcommittee for the Advancement of Small and Medium Enterprise Competitiveness (task 2.3);
4. The definition of possible business models for NeXOS products (task 2.4);
5. The development of industrialisation plans for market introduction using the business models selected (task 2.5);

Task 2.1 focuses on the overall market size of the market for environmental monitoring, the types of services currently offered as well as the types of equipment involved. Also the nature of the clients and the relevance of monitoring data are investigated. Based on the outcomes an indication of the current market size is made, however it should be noted that the figures presented are to be considered indicative as the market is very scattered and diverse and no consistent data are presently available. Also the expected trends in volume and available budgets as well as a shift in demand for specific markets are considered.

Task 2.2 assesses the competitive position of the European suppliers in the global industry. It is vital to assess the competitive position, since the feasibility, and the success, of the innovations developed under NeXOS depends on this position. Other factors influencing the feasibility are the quality and advantages of the innovations compared to the products made by non-EU companies. Relevant elements included in the competitive analysis are the industry structure, the regulatory framework, the competitive environment and, business strategies and policy responses.

The outcomes of task 2.1 and 2.2 are the starting point for the remaining tasks within WP2, starting with task 2.3. Task 2.3 further builds upon inputs from WPs 3-7, where the actual innovations will be developed, and feeds task 2,4 in which possible business models for the introduction of the new innovations are designed Task 2.5 needs inputs from WPs 1 and 11. The picture below shows the interdependencies between WP2 and the other WPs.

FIGURE 1-3 : RELATION BETWEEN WP2 AND OTHER NEXOS TASKS



Source: Ecorys (2014)

1.3 Report structure

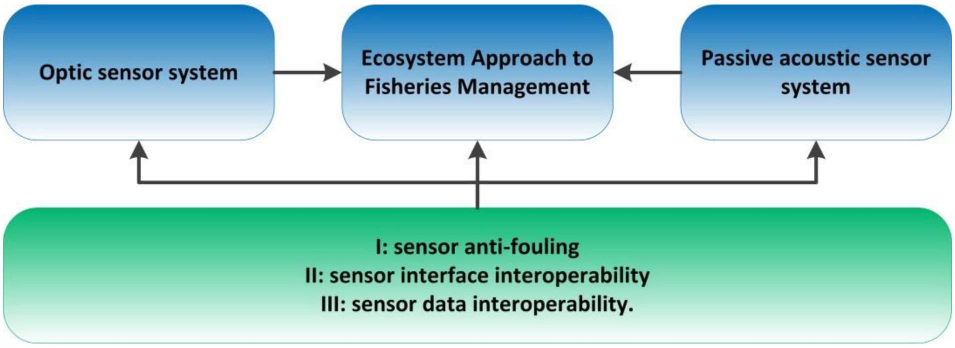
This report starts with a presentation of the methodological approach (in Ch.2), where the main market areas are presented as well as the structure for assessing the competitiveness of the industry. In subsequent chapters the components of this structure are further elaborated. Chapter 3 addresses the demand for sensor services and the various sectors calling for this demand. The supply side is addressed in chapter 4, where a value chain analysis is conducted. Main drivers for innovations in sensors and sensor applications are presented in chapter 5. These include technical demands but also regulatory and other drivers. Furthermore the competitive environment is brought to view. Building on these components, business models currently in place are assessed in chapter 6. Initial conclusions are given in Ch.7.

2. METHODOLOGICAL APPROACH

2.1 Types of sensor innovations addressed in NeXOS

Nexos addresses six main scientific and technical innovations. The first three innovations relate to the chosen observation framework, i.e. optic and passive acoustic sensors as well as an Ecosystem Approach to Fisheries management (EAF). The last three innovations are transversal and are applicable to all developments. They focus on sensor anti-fouling, sensor interface interoperability and sensor data interoperability.

FIGURE 2-1: RELATION BETWEEN THE SIX NEXOS INNOVATIONS



Source: Ecorys (2014)

As the figure above shows the six innovations are closely linked to each other. Below each innovation with the main R&D challenges is described.

Innovation 1: Optical sensor systems

For physical, chemical and biological processes in the oceans, light is an essential driver. Optical sensor systems are used to measure the different processes. Advantages of optical sensor systems are their long and successful history in measuring biogeochemical parameters and their potential for multi-functionality. Often optical sensors can be used for measuring different parameters at the same time. Parameters are measured using fluorescence and absorption, and these properties enable sensors to be used in long-term monitoring approaches.

Optical sensors are used in a wide range of different markets, ranging from the offshore oil- & gas industry and offshore renewable energy to fresh water measurements and aquaculture. Due to the wide range of applications and a large number of manufacturers a lack of standardized optical sensors occurs. Challenges to overcome, which are also addressed within NeXOS, are the size of sensors, power requirements and the measuring capabilities, with the ultimate aim to integrate the optical sensors on a variety of platforms, without extensive (manual) adaptation.

FIGURE 2-2: IMPRESSION OF DIFFERENT OPTICAL SENSOR SYSTEMS


Source: internal NeXOS website (to be checked)

Innovation 2: Passive acoustic sensor systems

Passive acoustic sensors are used to measure underwater noise in order to assess the impact of human activities on the marine environment as well as to gather data on subsea life (e.g. marine mammal research). In contrast to the use of sonars, passive acoustic sensors do not transmit energy into sea and thus have less impact on undersea life forms and environment. With the introduction of the Marine Strategy Framework Directive[10] (MSFD) the demand for passive acoustic sensors has increased and especially cost-effective solutions are sought. Up till now the use of marine acoustic sensors to gather acoustic data is rather costly.

Passive acoustic measurements are often done with hydrophones. The use of hydrophones has a long history as in many nations Navies have used hydrophones for many decades to detect threatening activities in their waters. Nowadays hydrophones are also used in other fields, especially for marine mammal hearing. Besides the use of hydrophones, passive acoustic measurements can be measured by digital applications which are introduced gradually. Digital hydrophones present an advantage compared to analogue versions in that they present no need for an adapter to transform the signals they receive into forms that can be processed. Additionally, analogue sensors require cables that can be applied for only limited ranges without compromising the quality of the transmitted signal.

In the NeXOS project the R&D efforts will mainly focus on the size of the passive acoustic sensor systems as well as their power requirements. Also the data transmission to on-shore facilities is important, as currently data are sent via satellite links which is expensive.

Innovation 3: Ecosystem Approach to Fisheries management

The Ecosystem Approach to Fisheries management (EAF) is not a specific sensor in itself, but a combination consisting of several optical and passive acoustic sensors. Aim of the EAF is to gather more precise data on the spatial distribution of the catch and the fishing efforts involved. The system can also be used to assess the quality of the fish stock, e.g. the weight and size of the fish.

Currently no universal system is in place and only a few pilots have been started, one of them being the Recopesca project led by Ifremer. The EAF system developed is voluntary installed on board of several French vessels and during regular fishing activities the system is able to measure the parameters needed. Main parameters measured are temperature, salinity and turbidity. As the system is installed on board of a fisherman's vessel the system needs to be easy operable, and so the sensors are attached to the fishing gear used and data are transferred to a computer program. To make EAF a successful system it is vital to ensure that fishermen do not need to undertake additional activities to set up the system or are hindered during the execution of their fishing activities.

To further improve the EAF system R&D efforts in NeXOS will focus on creating very low-cost systems which have a high autonomy (no interference of fishermen needed) and sensors that are able to better

[10] Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008 establishing a framework for community action in the field of marine environmental policy

measure chlorophyll and oxygen.

FIGURE 2-3: IMPRESSION OF PASSIVE ACOUSTIC SENSOR SYSTEM (LEFT) AND EAF SYSTEM (RIGHT)

Source: internal NeXOS website

Transversal innovation 1: sensor anti-fouling

One of the main transversal challenges to overcome, especially relevant for optical sensors, is biofouling. Sensors are operated under water and after a certain amount of time are no longer able to measure parameters due to biofouling. Especially during productive periods (bloom) biofouling can grow rapidly and within less than two weeks the sensors are not able to provide reliable data.

Within the last 20 years several solutions to decrease the effects of fouling have been developed, each with its own advantages and disadvantages. As a sensor often needs to be able to operate for several months or even years in a row without onshore maintenance, in an ideal case the sensor should have its own maintenance system to reduce the effects of fouling.

Some sensors are equipped with pills that contain chemical substances and each time the sensor needs to be cleaned such a pill is released. The high concentration of chemical substances is able to clean the sensor by dissolving the fouling; however the chemical remains are released into the ocean and might negatively affect the flora and fauna. Also the use of energy-based methods to counter fouling has been applied by some companies. This may include energising the water around the sensor with high voltage electricity or ultrasonic waves in order to kill or stun the algae or other microorganisms that attach on the sensors. Other solutions, such as mechanical removal of the substances hindering measurements may be more environmentally friendly by not damaging the surroundings directly, however they are not as effective in their cleaning operations or might pose power requirements that cannot be facilitated easily.

Biofouling frequently causes a shift in the quality of measurements, resulting in unusable data. The ideal solution for anti-fouling should be cost effective, have a low power requirement and should not interfere with the instruments or with the environment. Any new solution produced should enable coastal observation systems to work undisturbed for at least three months, while deep-sea observations should be able to operate for at least one year.

Transversal innovation 2: sensor interface interoperability

Usually, the monitoring of more than one environmental parameter is required; therefore multiple sensors can be installed onto an operating platform, e.g. buoys, gliders or ships. Most sensors are produced by small companies leading to a large variety of available sensors, each with their own capabilities, communication protocols, and data formats. The lack of standardization within the sensor market results in a need to (manually) adapt all sensors to install them on a given platform (interoperability gap).

To collect all data measured by an individual sensor software on board the platform is needed. The sensors often use generic or standard protocols, however these protocols often cannot directly be sent to the platform. To translate the data gathered by the sensor additional software is needed in order to ensure communication between sensors and platform. Nowadays, for each specific platform new software needs to be developed, which is a time consuming and complex process. Once the software is developed the next challenge is to provide (real-time) remote access to instrument data via the available communication means (usually satellite). Few instruments provide communications in a standard command protocol format, so additional observatory or shore-based software is required to transform the instrument data format to a standard that can be communicated.

Research efforts of NeXOS will focus on improving the sensor interface operability, preferably by developing a plug-and-play system. The system would enable to use all sensor types on all different platforms without extensive adaptation and software development. Result would be a cost reduction in system integration.

Transversal innovation 3: sensor data interoperability

Although at lot of marine data is being gathered, their use is still limited. Causes for this limited use are the format in which the data are gathered and the public availability. Marine data are gathered in closed silos and to use sensor data the format in which the data are collected need to be transferred to a format readable which is commonly used. Once the data are in a more common format they can also be integrated into marine data portals or data sharing initiatives such as GMES and GEOSS. Actions in the right direction already have been taken, but need to be further developed.

2.2 Scope of the economic viability analysis (WP2)

Definition of environmental monitoring

Environmental monitoring in the study's Description of Work (DoW) refers to all monitoring activities based on a regulatory obligation to measure the quality of the marine environment. Main source for environmental monitoring is the MSFD that sets the obligation for governments and other public bodies to monitor the quality of their coastal waters and seas. However marine monitoring activities consist of many more activities than the restricted definition used in the DoW.

Besides governmental organisations measuring the water quality, also universities and research organisations are monitoring the marine environment. For these institutions the main motive to do so is to obtain better insights into the ways seas and ocean eco-systems behave and develop. One of the focus areas of these institutes is the Artic region, an almost undiscovered area of the sea, but monitoring the quality of fish stock and mammal behaviour elsewhere are also part of ongoing research programmes.

Also industry, consisting of a diverse group of economic actors, has an interest in marine environmental monitoring. Their motives for marine monitoring may differ from those of governments, universities and research organisations. In some cases a legal obligation to monitor certain activities exists, e.g. the obligation to measure the quality of fresh water for water companies or the obligatory measurements of noise produced by the execution of economic activities for the oil &gas sector. Industry also voluntary uses sensors, especially when sensors can be used to optimize their business operations and could lead to cost savings.

Although many different companies use sensors for marine monitoring based on different motives, the sensor systems used are more or less similar. Different types of users can use the same sensors systems, whether their motive is based on a regulatory obligation or is more commercially driven related.

Geographical scope

This market assessment for environmental monitoring mainly focuses on Europe and European players. To assess the competitiveness of the European sector a detailed analysis at European level is required. It is important to analyse who the players in the European market are (ranging from the sensor developers to the end-users), how the market is organised, what their focus areas and available budgets are and what they consider as their market opportunities.

Where available, information on non-EU players is included in the analysis. Information of the rest of world (ROW), especially North-America, is provided in the competitiveness assessment, as their development and growth prospects will influence the position of European players.

Scope of this report

As described earlier this report covers task 2.1 'Market assessment' as well as task 2.2 'Competitiveness of the European supply industry'. Both topics are closely linked as the market assessment is one of the building blocks for the competitiveness analysis. Without a thorough market assessment it is difficult to assess the competitive position of European players. Therefore the first part of this report focuses on the market assessment, including a demand and supply side analysis of the European sensor market. In the competitiveness analysis, the second part of this report, the findings for the European sector will be evaluated vis-à-vis the sensor market in other parts of the world, especially North-America.

2.3 Methodology for market assessment

The methodology used for the market assessment is described in the this paragraph and the methodology to carry out a competitiveness analysis is described in the following one.

The first step in this analysis was to carry out a **literature review** to obtain an overview of the overall marine sensor market, trends and challenges. Starting point of the literature review where official documents of the EC, e.g. the Marine Strategy Framework Directive, GOOS, and Euro-GOOS. Secondly studies describing both the European and international sensor market have been reviewed as well as some technical papers relating to sensor qualifications.

Based on the literature review a questionnaire was developed which was used during two rounds of **interviews** held with consortium partners and other sensor users. The questionnaire can be found in Annex C and the list of interviewees in Annex D. The first round of interviews focused on manufacturers and developers of different sensors systems, while the second round contained system integrators, research organisations, universities and other end-users. Besides the interviews held by Ecorys in these two rounds, additional interviews were held by consortium members at Oceanology International[11] and the NeXOS steering group meeting[12].

Based on the literature review and the interviews held a description of the **value chain** was developed. The value chain covers all different actors in the sensor market and couples them to the different sensors development phases that where identified. The value chain has been extensively reviewed with members of the consortium and steering group members.

To validate the research findings a short **online questionnaire** was developed which was active from June to August 2014. To target this to parties outside the direct network of the consortium, a link to this questionnaire was published on the IEEE-website and distributed amongst relevant IEEE members as well as through the business network of consortium partners. The results of this questionnaire are used throughout the market assessment to verify and expand the findings of the interviews held. More details on the online questionnaire can be found in Annex E.

Based on the information gathered through the interviews and the online questionnaire a picture of the **current situation** of the sector was drafted. Also insights in the **trends** were derived. The current situation and trends differ per market segment in which sensors are used. Finally a **SWOT analysis** was carried out in order to identify the strengths, weaknesses, opportunities and threats of the European marine sensors manufacturing industry.

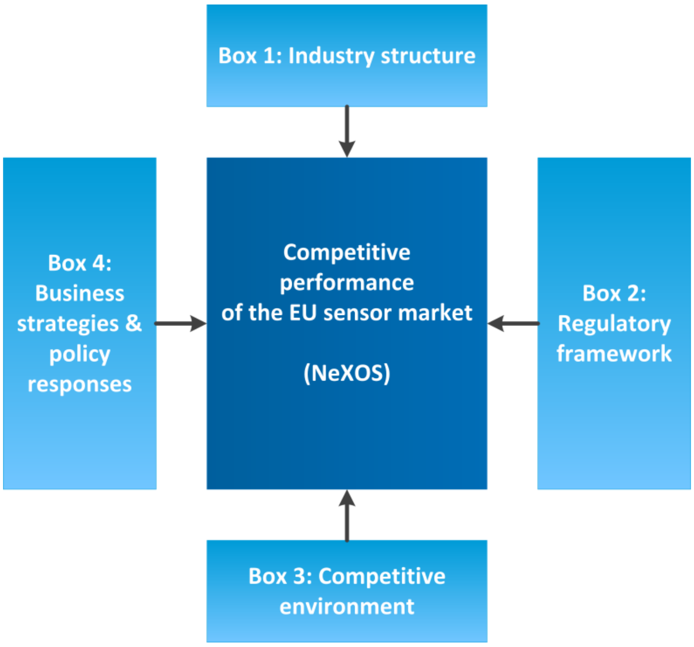
2.4 Methodology for the competiveness assessment

Closely linked to the market analysis is the competitiveness analysis. To assess the competitiveness of the European sensor market the framework presented in the figure below is used.

11 International conference held in London, UK on 15 -17 March 2014: http://www.oceanologyinternational.com/

12 Consortium meeting held in Runde, Norway on 1-3 April 2014

FIGURE 2-4 SCHEMATIC OVERVIEW OF ANALYSIS FRAMEWORK COMPETITIVENESS EU SENSOR MARKET



Source: Ecorys (2014)

The focal point in the competitiveness analysis is the European sensor supply & services market (dark blue box). This market has certain characteristics that are assessed in the market analysis. Further the competitive position and performance of the European sensor market are influenced by several other conditions. The competitive position and performance can be viewed as the outcomes of a complex set of supply-side and demand-side conditions. On the one hand the situation of the European value chain for each sub sector and the situation of the value chains of competing suppliers need to be analysed. On the other hand the performance of the sector market must be set in the context of developments within the final markets, including 'exogenous' factors such as overall macro economic environment and globalisation.

Both the supply-side and the demand-side conditions are influenced by the regulatory (and other framework) conditions that shape the level and the nature of competition within the final markets, and by the business models and strategies currently adopted by firms within the sector in response to these conditions and in response to the overall competitive environment that they face.

In the above schematic overview these relations have been summarised into four main (light-blue) boxes affecting the competitive performance of the European sector market. These boxes are described in more detail below.

2.4.1 *Box 1: Industry structure*

The industry structure has been divided into two components; the value (supply) chain and production process, and the access to resources. The value chain analysis focuses on the internal dimensions of the European sensor market and discusses the specific characteristics of the production structures in terms of types of players, company sizes, organisation of production processes and profitability.

The analysis of the resources mainly focuses on the production inputs needed in the sensor industry and the access to such resources. Examples of inputs needed are labour & skills, raw materials, capital and finance, energy, and knowledge and technology.

The primary aim of the industry structure analysis is to provide an understanding of how (European) production is organised, where and how value-added is created within the industry, and to identify those factors that are most important determinants (drivers) for value-added generation and enhanced competitiveness.

2.4.2 *Box 2: Regulatory and other framework conditions*

The sensor market is influenced by the regulatory environment and ‘other’ framework conditions. This part aims to assess the public policy environment that influences the competitive performance of the sensor market. The relevant regulatory issues can be split into:

Environmental related issues: due to an increased environmental awareness more and more monitoring activities become obligatory. Especially with the implementation of the MSFD and the subsequent monitoring guidance, it is expected that the sensor use will increase.

Other regulatory issues: these could relate to the applicable IPR regime, specific international trade barriers etc.

Essentially, this assessment is concerned with those factors – both from a supply-side and a demand-side perspective – in the general business environment of the sector that are or may be influenced through public policy initiatives. This may include measures or initiatives at national, regional (e.g. European) or international levels.

2.4.3 *Box 3: Competitive environment*

In the assessment of the competitive environment the focus lies on the assessment of market conditions and the level and nature of competition and competitive pressure in the main market segments. This competitive environment assessment consists of three core elements:

1. **Market (demand-side) developments:** e.g. identification and assessment of the main demand-side trends and developments
2. **Competitor (supply-side) developments:** e.g. identification and assessment of the main supply-side trends and developments related to the main competitors for European products and services.
3. **Exogenous factors:** e.g. globalisation, technology, environment, macro economic conditions etc. These factors will be analysed where relevant.

2.4.4 *Box 4: Business strategies and policy response*

The last part of the competitive analysis consists of the analysis of current business strategies and possible policy responses. This report solely focuses on the current business models used by the economic players in the value chain. Possible new business models that might be useful for the introduction of innovations made under NeXOS will be discussed in D2.2 (resulting from task 2.3).

3. DEMAND SIDE - MARKETS

To analyse the growth potential of sensor use in the different markets in which marine monitoring is used it is important to know why, how and how often sensors are used. Here, the product life cycle is introduced in the next section. Subsequently, the main aims of the sensor use will be explored, as this is considered an important factor to understand the drive for sensor development and market uptake.

3.1 The product life cycle

Once a product is designed, developed, and tested, it is ready to be brought to the market. At this point the product life cycle, also called the market development, starts which describes all stages a product goes through from its birth to its death. The product life cycle describes the adaptation rate of the product as well as the sales and profit levels that can be expected. The product life cycle consists of four specific phases, each with their own type of customers and market strategies.

Introduction phase

Once the product is market ready, the first phase in its product life cycle is its introduction phase. In this phase the product is presented to the market and generally the sales are slow. Potential customers, the so-called early adopters, need to be made aware of the new product and its possibilities. These early adopters are customers that are very willing to buy new and innovative products, often without an extensive track-record and often at relatively high prices. Manufacturers need to spend a large part of their budget to promote the new products, e.g. by organising promotion campaigns, presenting products at fairs and conferences and by personal selling. A large set of selling techniques needs to be used in order to persuade customers to try the product and in this phase the manufacturers are often not able to make profits. Competition in this phase is usually still limited.

Growth phase

In the second phase, the growth stage, sales are increasing as more customers become aware of the product and are getting familiar with its usefulness or attractiveness. These customers are often indicated as the early majority that is willing to buy new and trending products. The manufacturer will be able to make larger profits and cover the development and introduction costs of the product. Often the number of competitors is growing rapidly as well during this stage, as others seek to seize the profit opportunity. Strategies for the manufacturer will be to establish and maintain a loyal customer base and the R&D efforts will focus on improving the product in order to sustain sales growth as long as possible.

Maturity phase

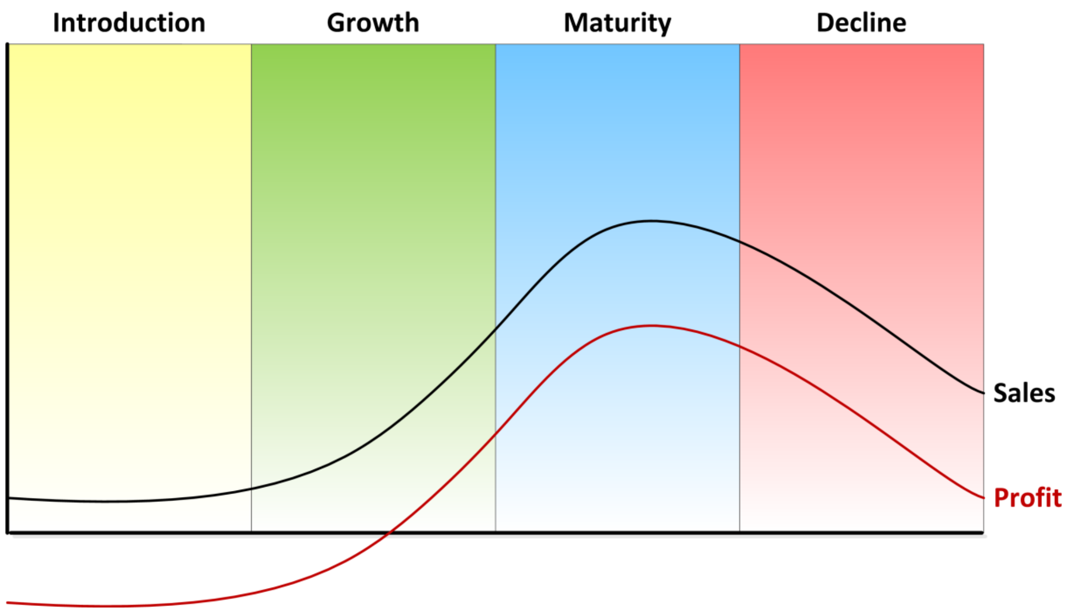
In the maturity phase the market for the product is stabilizing. Initially the sales volumes will increase, but in later stages of the maturity phase the sales will stabilise and potentially also start to decline, as the market is becoming saturated. R&D efforts are limited and the profit margins are positive but flat or even declining. It becomes more difficult to maintain a loyal client base as many competitors offer similar products and some customers are searching for new types of products. New customers, the late majority, can be added. The late majority often wants to buy established and well-proven products. A product can remain in this stage for quite long.

Decline phase

The last phase of a product is the decline phase. In this phase some new clients, the laggards, can still be found, but the majority of the client base will no longer buy the product. The sales volumes start to decrease rapidly and also the profit margins are decreasing. The number of competitors will reduce as some of them will decide to leave the market or differentiate their products. Also a share of the customers will stop using the product. A product can be in this stage for a long time, as long as the product has a loyal customer base that makes it worth to continue producing (lower amounts of) the product. If the product is no longer used, its production will stop and the product has 'died'[13].

The figure below shows the typical trend-line of sales and profit associated to the various market development phases. Of course this theoretical function in reality is affected by the actual circumstances in the specific market concerned. For instance profitability could lag more from sales in markets where high development and upscaling costs are to be incurred. Also, at the end of the market cycle, prices sometimes may need to be lowered in order to compete with newer technologies introduced, negatively affecting profitability.

FIGURE 3-1 MARKET DEVELOPMENT PHASES



Source: Ecorys (2014)

Typical characteristics of each phase

As described above each market development phase has its own characteristics which regards to sales volumes, profits, cash flow, type of customers and competitors. Following table summarizes these characteristics per phase.

TABLE 3.1 CHARACTERISTICS PER MARKET DEVELOPMENT STAGE

	Introduction	Growth	Maturity	Decline
Sales	Low	Fast growth	Slow growth/Stable	Decline
Profit	Negligible / negative	Positive to flat	Flat to declining	Low to zero
Cash flow	Negative	Moderate	High	Low
Customers	Innovators	Early majority	Late majority	Laggards
Competitors	Few	Growing	Many rivals	Declining number

Source: Douglas Hoffman et al. (2005)

The duration of the entire product life cycle and of each phase differs per product. Some products have a very short life time, with very short introduction and growth phases, while other products have a very long life span and can remain in their maturity phase for many years. For the marine sensors the market development phase needs to be assessed per market. This will be done in more detail in the next section.

13 Examples of products that have effectively died are the typewriter, Walkman and gramophone (although the latter appears to be experiencing a revival).

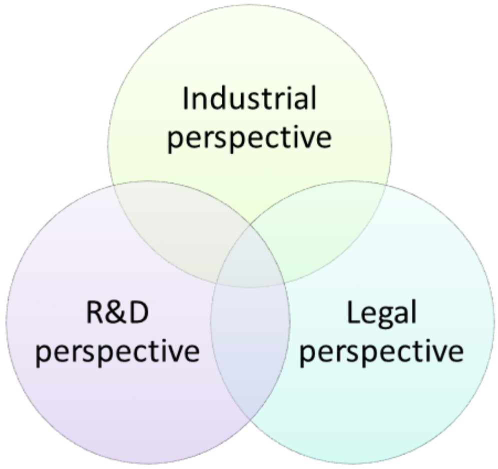
3.2 Aims of sensor applications

The reasons of using marine sensors differ per market sector. The differences between the aims will influence the potential sensor development for that specific market. We distinguish three types of aims: the R&D perspective, industrial perspective and the legal perspective.

- Legal aim: monitoring of the marine environment because legislation requires an actor to do so
- Industrial (commercial) aim: an economic operator uses sensors to monitor or steer its processes, as they are considered the most economically advantageous way to do so
- R&D aims: the use of sensors for the sake of science, without a pre-defined application in mind.

For most market sectors assessed all three aims can be relevant and the use of sensors can serve multiple aims at once. Especially the R&D perspective is often influenced by the industrial and/or legal perspective.

FIGURE 3-2 RELATION BETWEEN THE APPLICATION AIMS



Source: Ecorys (2014)

Legal

The legal perspective is, for European players, mainly based on EU legislation. Main Directive is the MSFD, adopted in 2008, aiming to support a sustainable and integrated approach to monitor the ocean. Each Member State with coastal waters, is required to develop a national strategic framework. The European Commission evaluates each national proposal and ensures that no conflicts of interest between the national plans occur. The MSFD includes the initiatives to satisfy the Good Environmental Status (GES) of marine waters, the Data collection framework for Fisheries (DCF), the INSPIRE directive and the Blue growth communication.

Based on the current legal framework economic actors are obliged to monitor the environment or the effect of their activities on it. Under the legal framework the use of sensors to monitor the effect on the environment is not mandatory. Other means to achieve the same results are allowed, however many actors seem to prefer sensors, because they are cost-effective and can provide robust and concise measurements. Given the wide range of methods used, the Commission issued criteria and methodological standards on the GES.[14] Research institutes, including oceanographic institutes and universities, are more involved in the general execution of the MSFD, by carrying out general environmental monitoring activities, while industry players fulfil a specific obligation. For example the offshore oil & gas industry is obliged to measure the noise levels it produces to assess the impacts on marine mammals and fish stocks near their installations.

[14] COM(2010)477: Commission Decision on criteria and methodological standards on good environmental status of marine waters

Economic

The economic perspective is mainly based on improving business operations. The use of sensors enables the different operators to better monitor the daily operation of their equipment and installations and can assist in optimizing maintenance schemes. Main advantage for operators is the possibility to reduce operating costs. Depending on the specific market segment economic actors are more aware of the advantages of sensor use in their production process.

In the oil & gas industry the benefits of sensors are well known and many companies already use sensors to monitor their installations, e.g. in order to detect unexpected maintenance needs. By applying these new monitoring techniques they are able to save large amount of moneys. In other sectors the use of sensors is much less advanced and economic actors need to be made aware of the possibilities. For instance in aquaculture most companies do not yet see the benefits of using sensors. Several interviewees expect that with the communication of best practises the use of sensors may increase in this sector as well.

R&D

Research and development is often not done on a stand alone basis, but is connected to legal and/or economic motives. For example, to use sensors to monitor oil & gas installations it is important that sensors are stable in order to obtain reliable data. R&D needed to develop stable sensors is influenced by the economic benefit oil & gas companies have to use sensors in their production processes. They will ask sensor developers and manufacturers to sell them stable sensors.

Besides the R&D needs linked to economic or legal motives, some general R&D needs have been identified which apply to all types of sensors irrespective of their uses. Examples are the need for smaller sensors in order to be able to easily implement them on a platform, the need for standardisation and overall power requirements. These needs are described in more detail in chapter 5.

3.3 Assessment of market sectors

The different sensor types analysed within NeXOS, optic, passive acoustics and EAFs, are used in different market sectors. Also the platforms used are not specific for individual market sectors. Some sectors might have a stronger preference for specific sensors and platforms, however none of them is exclusive. Therefore the starting point of the market assessment is the analysis of the different market sectors which use marine sensors. For the main market sectors a short description will be given, including an overview of the main challenges and barriers, the growth potential and geographical scope. Also the main aims of the sensors' uses will be discussed.

The market segments distinguished are:

- Monitoring of environmental quality
- Offshore oil & gas industry
- Industrial water quality measurements
- Oceanographic Research
- Fisheries
- Aquaculture
- Offshore renewable energy
- Deep sea mining
- Port security

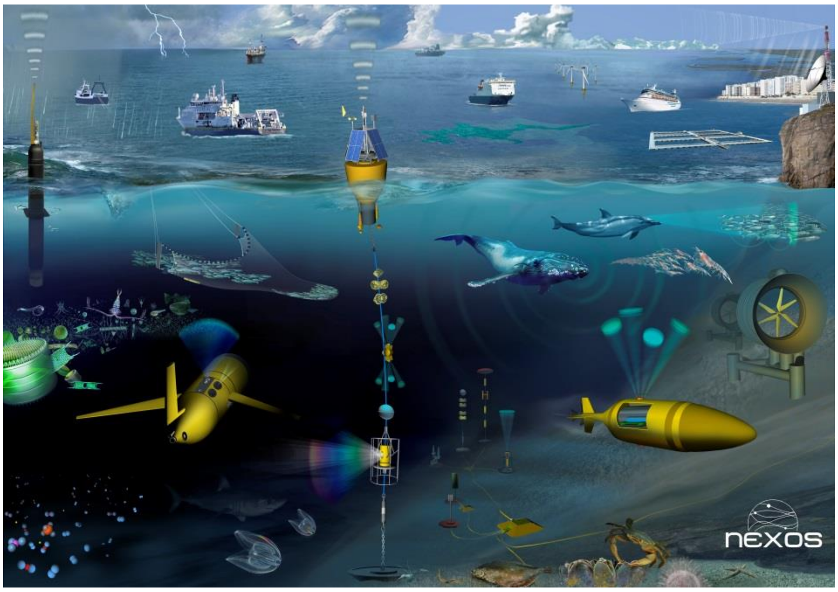
3.3.1 *Monitoring of environmental quality*

This market relates to environmental monitoring in the strictest sense of the world. Activities carried out in this market are all based on the MSFD, which obliges governments and public bodies to measure the quality of their coastal waters and seas. Measuring the quality is not done on a voluntary basis. The MSFD does not regulate that sensor systems should be used, however many public bodies do chose sensors as there are often more cost effective than other solutions and are able to provide robust and concise data sets.

When the MSFD was adopted sensor manufacturers and research organisations, including universities, expected a rise in sensor use. Until now adaption rate has not speeded up immensely. This could be caused by the fact that the MSFD has a time frame until 2020 which might encourage public bodies to postpone their monitoring duties, in combination with decreasing public budgets, as a result of the economic crisis.

The GES, now incorporated in the MSFD, provides an overview of the parameters that need to be measured in order to achieve the goals set by the directive. The research needs in this market are based on that list of parameters in order to be able to comply with the rules.

FIGURE 3-3 IMPRESSIONS OF ENVIRONMENTAL MONITORING ACTIVITIES



Source: NeXOS Consortium

Geographical scope

The MSFD applies to all EU-28 members and the EEA countries (Iceland, Norway and Liechtenstein), so for all these countries an environmental monitoring obligation exists. Outside Europe not many countries have adopted similar legislation, so this market is currently limited to the EU market.

Aims

As stated above the research aims in this sector mainly relate to the possibility to measure the parameters that need to be measured based on the MSFD in a reliable and efficient way. The environmental monitoring market shows a direct link between the legal perspective (reaching the goals set in the MSFD) and the R&D needs.

3.3.2 *Offshore oil & gas industry*

Sector description

The offshore oil & gas industry is a well-established industry. With regard to the application of sensors the oil & gas industry can be qualified as a growing market. Many companies are already using sensors in their daily operations and it is expected that sensors use will increase the coming years.

The industry has two reasons to use marine sensors. The first reason for sensor use spurs from an industrial perspective. Sensors can be employed at offshore platforms, pipelines and other equipment in order to detect and prevent possible oils spills. Also the quality and timing of maintenance can be improved by using sensors. These activities will result in reduced maintenance and repair cost for the operators. Secondly there is often a regulatory obligation to monitor mammals and fish stocks as they are negatively influenced by drilling activities and other noises resulting from oil platform operations. The industry is obliged to shortly interrupt activities when mammals are approaching. Mammal detection becomes more efficient with sensors use.

The sector has the availability of large budgets and therefore can easily buy or rent[15] sensor systems and the decision to buy or rent a certain sensor system is based on the capabilities of the sensors rather than their price. Also sensors need to have a proven track record. Most companies are asking for sensor references, showing that the sensor is actually measuring what it promises. Important is also that the references do not only show the results under the most promising circumstances, but also show that a sensor works in real life situations, e.g. rough waters and strong currents. The sector is often not willing to use sensors that are not proven yet. However it happens that companies would like to measure certain parameters, and only sensors without references are available.

Important capabilities of sensors, that also steer the research focus are sensor stability in rough waters, consistent and robust data measurement, the number of parameters to be measured and possibilities to transfer real-time data. Especially this last point is essential as possible oil leakages can be detected in an earlier stage once data are transferred directly to the control centres.

Sensor use in the offshore oil & gas sector has a large growth potential which will further increase when regulation is adopted with regard to environmental performances and reducing the negative impact of the oil & gas industry, e.g. pollution and noise levels.

Geographical scope

Players in the offshore oil & gas industry mainly focus on areas where oil & gas have already been discovered and where drilling activities can easily take place. Drilling activities require a sufficient amount of monitoring and these activities can be carried out by sensors. Within Europe the focus is on the North Sea, including Norway, the Adriatic Sea, central and eastern Mediterranean Sea and the Black Sea[16]. Besides the areas where oil and gas reserves are known to be present, companies are focusing on areas where there is a likely chance to find oil and production could start within several years. Some oil & gas companies are carrying out monitoring activities within the Artic region to get familiar with the environmental conditions in this area. This knowledge can be used if/when oil activities become reality in the Artic.

Aims

Based on the interviews and information gathered the following research aims can be identified:

1. sensor stability: the sensors operate in rough waters and in order to ensure good data quality sensors need to be improved.
2. data transmission: to be able to prevent oil spills, it is important that operators can act immediately when something happens. Therefore real-time data transmission needs to be made possible, and cost-efficient.
3. Increasing the number of parameters: to detect mammals efficiently it is important that the mammals can easily be detected in an area where noise levels are high as a result of drilling and other industry activities. Also to be able to carry out the maintenance efficiently sensors need to be able to measure a wide range of parameters.

The industrial or economic reasons to use sensors are the ability to improve maintenance activities and to assist in the prevention of oil spills due to an earlier detection of leakages.

From a legal perspective sensors are used in the oil & gas industry in order to esp. reduce the impacts of drilling activities on marine mammals and fish stock.

15 In most cases the oil companies do not own the sensor system, but they rent them from service providers. These service providers are also gathering all data needed and might even assist in the data analysis.

16 Ecorys (2012)

3.3.3 *Industrial water quality measurements*

Sector description

Sensor use in the fresh water market is well established and is nearing the maturity phase in the product life cycle. No large growth is expected in this market. The fresh water market refers in this context to the industrial water quality measurements. This sector is interesting for marine sensing as spill-over effects between the fresh water and salt water market occur. Also some of the economic actors, especially the service providers, identified in the value chain are the same in both markets (see Ch.4).

Sensors are used to measure changes in the water chemistry as well as its quality; often Particulate Matter (PM) measurements are carried out. Sensors are mainly used to optimize business operations. For instance water companies use sensors to monitor their water quality and are able to better adapt their maintenance schedules, which allows for costs reductions and leads to improved efficiency. Other applications include salinity measurement in rivers with strong tidal influence, e.g. to inform farmers about the water quality and its suitability for irrigation.

In the fresh water market, price of sensors/data is a more important factor than in salt water markets where reliability is vital. The requirements for fresh water sensors attributes usually emphasise less on measurement accuracy compared to marine sensors, and for instance biofouling is less of an issue. This is because in fresh water the fluctuation of environmental parameters is larger and exact values are not as important as the capacity of sensors to operate in the whole spectrum of possible values.. This makes the operation of fresh water sensors less costly than the operation of marine sensors as fresh water sensors often are connected to buoys or other fixed and shore-connected platforms, while marine sensors often need to be connected to highly advanced (e.g. remotely operating) platforms or to vessels. Costs for renting a maritime vessel for a longer period can amount to millions of euros and the costs of other platforms, like gliders, can be several ten thousands of euros as well.

Geographical scope

Fresh water sensors are already used by many water companies and companies using water in their industrial processes, in Europe and North-America. Also public authorities and other organisations may use various sensor applications of this kind to ensure reliable water supply.

Aims

During the analysis no clear research needs have been identified as the market for fresh water sensors is relatively matured and technology is sufficiently developed. The spill-over effects from the marine sensors, which can measure more parameters and are more accurate, are limited, as marine sensors are expensive compared to fresh water sensors. Most companies do not have budgets available to buy these expensive marine sensors and there is often no need for higher levels of accuracy.

The industrial or economic aim to use sensors is to improve business operations and enable the company to reduce its maintenance budgets.

From a legal perspective no indications have been found that companies need to use sensors in their daily operations. However, before water can be sold, the water has to fulfil certain quality standards, for which the use of sensors is a cost-effective means.

3.3.4 *Oceanographic research*

Sector description

The research industry – if one can consider research an 'industry'[17] – is a fast growing and almost mature market. Main focus of research is on environmental monitoring in the broadest sense of the word, i.e. Artic research, mammal observation, water quality, fish stocks etc. This sector consists of oceanographic institutes, universities and a variety of other research organisations. Besides carrying

[17] In the sense of this market assessment, the research community is highly relevant as a purchaser of (new/innovative) sensors,

out the actual data measurements, these economic actors are also often involved with the sensor development and for this reasons they closely cooperate with the sensor manufacturers.

Research institutes often do not call for standard 'off-the-shelf' sensors, as these sensors are not able to measure the parameters required in the specific research program. Therefore sensors often need to be adapted to the specific research needs. However this adaptation of the sensors can be costly. Research budgets are limited and it is expected that these budgets will be further reduced in the future driven by public deficits across Europe. Also buying procedures take long as universities and research institutes need to find funding to buy new sensors and have them adapted. From the perspective of a sensor supplier serving this market is a time consuming and costly process.

Environmental awareness is the main driver in the research sector. The adoption of the MSFD has further increased the research to be done. However, some of the stakeholders indicated that the MSFD did not bring the expected results. It was generally thought that with a compulsory environmental monitoring system research activities would increase considerably, but, until now, this did not happen.

FIGURE 3-4 DIFFERENT PLATFORMS FOR ENVIRONMENTAL MONITORING; BUOYS (LEFT) AND GLIDER (RIGHT)

Source: Plocan

Geographical scope

The geographical scope depends on the research topic covered, but marine research is taking place all over Europe: in most countries local institutes are involved in researching the territorial waters of the country concerned. Beyond that, research interest is found across all European seas and oceans,

Aims

General research aims that, from the perspective of the research sector, need to be addressed, are the size of the sensors, their energy consumption and the sensor and data interoperability. Sensors need to be included on a platform containing several sensors and with limited space available, hence the size of each sensor is important: the smaller the sensor the more sensors can be included. Also the energy consumption of each sensor and the platform is important as the platforms can be away for months or even years with a limited power supply.

From an industrial perspective research institutes can help to develop sensors that can be used in other sectors and they can help to collect and analyse data. For instance quite some information is sold to the oil and gas industry and it is expected that the same services can be sold to other industries, e.g. offshore renewable energy or fisheries.

From a legal perspective activities are mainly based on the MSFD and to perform general environmental monitoring services.

3.3.5 Fisheries

Sector description

The use of sensor systems in the fishing sector is still limited. Information on the quality and quantity of the fish is based on actual fish catches and assumptions made. An EAF system can be used to better monitor the availability and quality of different fish stocks. The system, consisting of several optical and passive acoustic sensors, is attached to the fishing gear used. During the general fishing activities data can be gathered and once the fishing gear is brought back on board the data can be downloaded. Main parameters measured are temperature, salinity and pressure of the water. To further improve the possibilities of the system, also oxygen and chlorophyll should be measured.

Currently fish related monitoring projects are led by research institutes. Research institutes develop the system requirements, and analyse the data. The data are shared with the fishermen, who can use these data to plan their operations more efficiently and possibly to better negotiate fishing quota. The EAF measurements will not replace the quota as quota are legally binding and EAF can only be supportive, by providing additional information which can lead to quota better reflecting reality. To persuade fishermen to take part in EAF projects, not only the sharing of the data is important, but also the handling of the system is important. An EAF system should not interfere with fishing activities and force fishermen to do a lot of additional work. Therefore the simple attachment of the system to the nets and easy data downloading is essential.

Although EAF systems are available on the market for 7-8 years already, their use is still limited as the system is rather complex to use and is expensive, as each vessel participating in the data gathering exercise needs to be equipped with its own system. To have adequate data measurements for a region a large number of vessels is needed, e.g. to cover the whole French territorial sea around 300 vessels would need to participate. For the whole of Europe between 1,000 and 2,000 vessels would be needed depending on the desired data density.

Currently no regulation is in place that states the fish stock should be measured in this thorough way. Also the use of EAF is not laid down in any legislation. The only relevant legislation is that of defining the fishing quota for each fish species. It is a better adjustment of these quota, to a more dynamic definition of the fishing volumes allowed, in close connection with the fish stocks available, that is targeted by the EAF system.

Geographical scope

Currently sensors systems are not widely applied. The Recopesca project[18] is running in France and several French vessels are currently equipped with measuring tools. Also in Italy a pilot has started using an EAF system. In Norway discussions on starting an EAF pilot project are currently ongoing. If the EAF pilot projects are successful the market (i.e. the demand for the sensors used in EAF) can be expanded both in Europe and other fish-rich parts of the world.

Aims

Based on the interviews held the main research aims related to fisheries (EAF) are:

1. Developing compact systems that do not hamper fishing activities, but at the same time are able to sufficiently measure the quality and quantity of fish;
2. Ensure easy downloading of data, so that the measuring of data does not interfere with general fishing activities and leads to additional work for fishermen. Additional work will diminish the uptake of the system;
3. The ability to measure oxygen and chlorophyll. Currently these parameters cannot be gathered, but they would further improve the data measurements.

The industrial or economic aim to use an EAF system is to be able to monitor the quality and availability of certain fish in a more efficient way, and to use this data to plan fishing operations more effectively. Fishermen can potentially use this information also to negotiate on fish quota.

18 http://wwz.ifremer.fr/peche/Les-defis/Les-partenariats/Avec-les-professionnels/Recopesca

3.3.6 *Aquaculture*

Aquaculture is the rearing or cultivation of aquatic organisms using techniques designed to increase the production of the organism in question beyond the natural capacity of the environment. Aquaculture involves both the growing of algae and the the farming of aquatic animals, e.g. oysters, shrimps, salmon and sea bass.

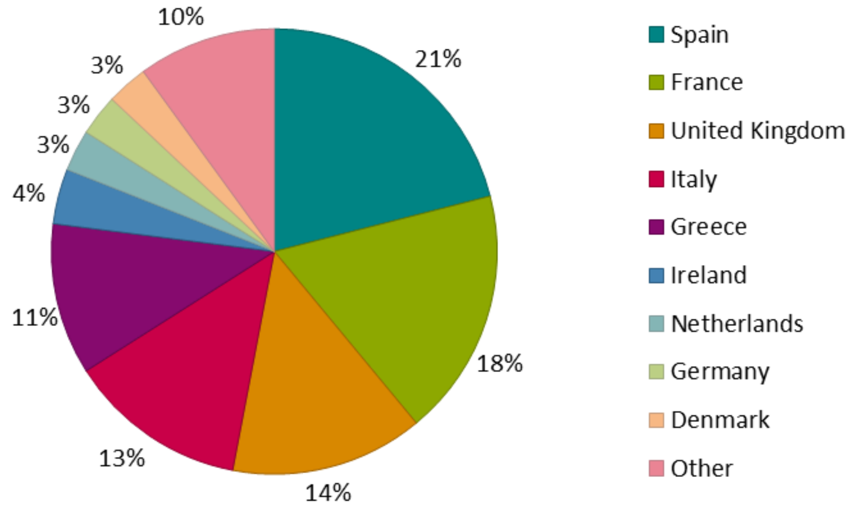
Aquaculture itself already takes place for several years and some of the subsectors have a long farming tradition. However the use of sensors to support business operations is relatively new. Main motivation to use sensors is to monitor the quality of the animals or crop and to change the production process once defects are detected. Sensors can also be used to protect the animals or crop by detecting possible treats and diminish their effect on the aqua farm. Furthermore sensors may be used to measure the impacts of aquaculture on the environment in which the farming takes place, i.e. to avoid eutrophication.

Regulation is in place that obliges aqua farmers to monitor the status of their equipment used and their production process[19]. The regulation is in line with other health and safety regulation applicable in the EU. Sensor use is an attractive way to comply with the regulation as it is costs-efficient.

Geographical scope

In Europe, Norway is the biggest aquaculture country. Within the EU the country with the largest share in aquaculture is Spain. Of the 1.28 million tonnes produced by the EU-28 countries in 2011, Spain produced 21%. Spain is followed by France, the UK, Italy and Greece. The share of the other EU members is considerably smaller.

FIGURE 3-5 AQUACULTURE IN EU PER MS IN WEIGHT: 2011



Source: JRC Scientific and policy report (2013), edited by authors

In 2011 the value of aquaculture products was 3.5 billion Euros for the EU-28 countries. The value of the UK was the highest (20%), followed by France (19%), Greece (15%), Spain (12%) and Italy (10%).

Aims

The research aims called for by the aquaculture sector relate to the operational capabilities of the sensors. Many aquaculture activities take place in areas with strong currents, and therefore sensor

[19] Commission Regulation (EC) No 710/2009 amending Regulation (EC) No 889/2008 laying down detailed rules for the implementation of Council Regulation (EC) No 834/2007, as regards laying down detailed rules on organic aquaculture animal and seaweed production

stability is important. If the sensor is not stable, the data measurements will be interrupted and the data measured cannot be used. Secondly it is important that the sensors do not interfere with the aquaculture process. The system should be designed in such a way that the animals or crops can grow freely and their development is not hampered by a complex sensor system.

From an economic / industrial point of view it is interesting to use sensors systems as they can on the one hand detect possible treats to the animals and crops and on the other hand they can measure the quality of the animals and the crop. The data gathered can be used to improve the growing process.

3.3.7 *Ocean renewable energy*

Sector description

The sector of ocean renewable energy has similar characteristics as the offshore oil & gas, however both the sector itself and its sensors use are less developed. Ocean renewable energy is upcoming since about 20 years and the use of sensors is even more recently adopted. Main reasons to use sensors are to support maintenance activities and to reduce the overall operational costs.

The ocean renewable energy sector is diverse and consists of several subsectors, each in its own development stage. The most advanced subsector is offshore wind. This sector has been stimulated over the past the years and several wind farms have already been established, throughout Europe. It is expected that the subsector will further grow, as the European Commission has set rules with regard to the share of renewable energy every member state should realise, and wind energy is considered an important contributor to this for a number of countries. Less advanced subsectors are tidal and wave energy. These sectors are still in their development phase and it is unclear whether or not the technologies developed will become a success.

Currently no legislation is in place obliging ocean renewable energy producers to monitor their equipment. However it can be expected, that with the increase in especially offshore wind farms, regulation will be adopted. Offshore winds parks are built further away from shore interfering with other marine activities, e.g. interrupting the habitat of several types of marine mammals.

Geographical scope

In 2012 offshore wind installations in Europe were mainly installed in the North Sea (65% of all capacity[20]), followed by the Atlantic (19%) and the Baltic Sea (16%). Countries with the largest wind farms are the UK (52% of all capacity installed), followed by Denmark (25%), the Netherlands (7%) and Belgium (5.5%). Europe is the world leading place for offshore wind installations. In 2012 90% of all capacity was installed in European waters. Other areas where offshore wind installations are installed are China (9%) and Japan (1%)[21]. In total 5.538 MW was installed globally.

Aims

Several research challenges with regard to sensor use in the offshore renewable energy sector have been identified:

- Firstly, a variety of optic and passive acoustic sensors are used to monitor equipment performance. One of the major technical challenges for these types of sensors is to deal with bio-fouling. For the renewable energy sector an effective anti-fouling system is useful.
- Secondly, power requirements play a role. The sensors are attached to the installations and need power to operate. Currently the power is supplied through cables connected to shore. However most operators would like to decrease the number of cables needed as they require intensive maintenance which increases the operational costs.
- Thirdly, data transmission is important. A large amount of data is collected which needs to be sent to shore. Nowadays data are transferred by cables and these are not desired by operators.

Industrial motives for sensor use are the possibility to improve maintenance operations as defects can

[20] It should be noted that the capacity mentioned was not solely built in 2012, but between 1991 and 2012.

[21] EWEA (2013)

be detected in an earlier stage. Also the collection of operational data becomes easier once the installations used to generate renewable energy are equipped with sensors.

3.3.8 *Deep Sea Mining*

Sector description

Deep sea mining (DSM) is the activity where minerals like poly-metallic nodules, poly-metallic sulphides; and cobalt-rich crusts are extracted from the sea bed. These mining activities would take place at great depths ranging from 800 to 6,000 metres. The market for deep sea mining is currently non existent apart from some research and exploration activities. Driven by increasing prices for land-mined raw materials, this market might develop as a new source of minearals, although a number of technological challenges still needs to be passed and still then exploitation costs will be substantial.[22]

The different sensor types analysed within the NeXOS project can be used by the deep sea mining sector. First of all these sensors can help to gather sea floor related information which is useful for the exploration activities taking place now as well as possibly for the actual mining activities later-on, for example to monitor changes in the sea bed eco-systems caused by the mining activities being carried out. Secondly, sensors can be used to monitor the status of the equipment and indicate if maintenance activities are sufficient or not.

The sensors used in deep sea mining activities need to be able to operate at a large depth, where pressure is higher. This will influence the data measuring capabilities. Also the energy consumption of the sensor is a challenge as sensors need to operate for a longer period of time without recharging possibilities.

Currently no legislation is in place regulating sensors using in deep sea mining, as deep sea mining is a non-existing activity. Although the market is expected to grow, this growth is not expected within the near future. On the one hand, mining equipment is very expensive and also carrying out such activities is economically not beneficial, as the cost are substantially higher compared to possible profits. On the other hand most countries do not grant mining licenses for deep sea mining activities.

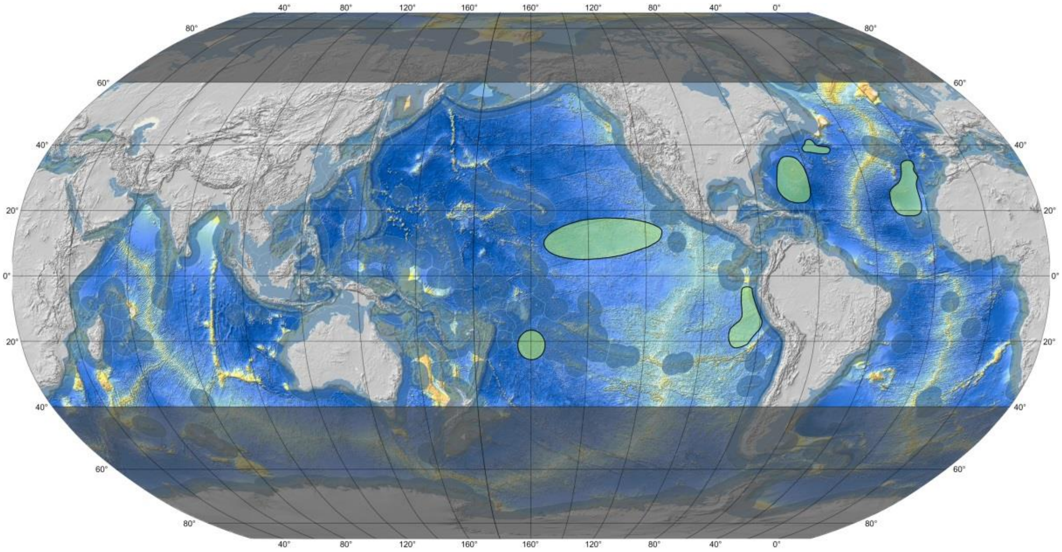
If deep sea mining really starts to take off as an economic activity it might be expected that legislation will be introduced. Similar to the offshore oil & gas industry deep sea mining activities will disturb the living environment of mammals and fish. Noise levels and turbidity probably need to be measured in order to ensure limited effects for the deep sea fauna.

Geographical scope

The most interesting areas for deep sea mining activities are located in the Area Beyond National Jurisdiction, the so-called Area, the Area that belongs to the common heritage of mankind and does not belong to one specific country (the seabed below international waters). Current exploration activities are concentrated in the Pacific mainly. In a recent study carried by Ecorys and others, the availability and location of the three above mentioned minerals have been assed. Based on this study the most likely mineral to be mined are the manganese nodules. The figure below shows the most likely areas (green areas).

[22] Ecorys (2014) Study on the state of knowledge of deep-sea mining (forthcoming)

FIGURE 3-6 ARAS CONTAINING MANGANESE NODULES (GREEN AREAS)



Source: Ecorys (2014)

Aims

Research challenges are to improve the ability of sensors to measure at a greater depth. At these great depths pressures are much higher and this influences the usability of the sensor. Also energy consumption of the individual sensor as well as the platform is important. The sensor systems need to operate autonomously for several months without recharging possibilities.

Industrial or economic motives to use sensors are similar to the motives in the oil & gas industry. Sensors can be used to monitor the status of the equipment and indicate whether or not additional maintenance is needed. Overall the operation of installations can be approved. Sensors can also be used to monitor the sea bed and optimize the mining activities, because more accurate information is available.

3.3.9 *Port security*

Sector description

In the context of NeXOS port security is understood to relate to all monitoring activities carried to detect underwater threats or to measure noise levels of port activities. So, for instance, terminal surveillance carried on land is not included within the scope of NeXOS as these activities do not require marine sensors.

Port security can be seen as a market in its introduction phase. To detect possible threats other measuring tools are often used, e.g. sonar tracking and camera surveillance. Navy ports have a long tradition of using sonars to detect asymmetric threats and protect against them. However the use of sonars is especially harmful for underwater sea life and mammals in particular, while it can also prove dangerous for divers performing activities in the vicinity of the port. Therefore the use of sonars is limited to a few important military locations while for civil ports they are not considered an option.

The use of marine sensors is relatively new in this sector and needs still to be proven and acknowledged. In the port security sector mainly passive acoustic sensors are used. Measuring noise levels is compulsory in European ports. In addition hydrophones can be used to detect 'undesired' underwater activities. Current challenge to spur the introduction of passive acoustic sensors in this market is to be able to detect divers. This group forms a potentially large threat, because they can attach bombs on vessel hulls triggering big explosions within ports. Passive acoustic sensors are developing towards improving their detection although they cannot sufficiently detect their movements under all environmental circumstances and settings in the rather noisy environment they have to operate yet.

The EU is also conducting maritime transport security inspections to ports and ship facilities in cooperation with EMSA and EFTA. This streams from repeated EU directives on maritime security.

Geographical scope

In principle sensors can be used in every port around the world. However depending on the applicable legal framework it needs to be assessed whether or not sensors can be used. Also the use of sensors is not yet acknowledged everywhere. Currently ports in Europe do use sensors in their monitoring activities. It is not expected that the use of sensors will increase rapidly.

Aims

The research challenges in the field of port security are difficult to identify, because confidentiality plays a large role in this sector. The only challenge identified relates to the use of hydrophones. These hydrophones should be adapted so they are able to hear divers, which can form an asymmetric threat.

From an economic point of view it is interesting for ports to use sensors instead of sonars or other measuring equipment in detecting possible terrorists' attacks as this can influence the insurance fees they pay, should they be capable of proving that their monitoring activity reduces asymmetric threats to a port's security. According to the International Ship and Port Facility Security code (ISPS) each port is required to take measures against asymmetric threats. Moreover the level of provided security measures can influence the premiums ports pay for being secured against a terrorist attack. Should a port be able to exhibit that by using sensors it is easier to detect possible threats and as a result it is able to reduce the risk of such an attack, insurance companies should in principle be willing to reduce the fees.

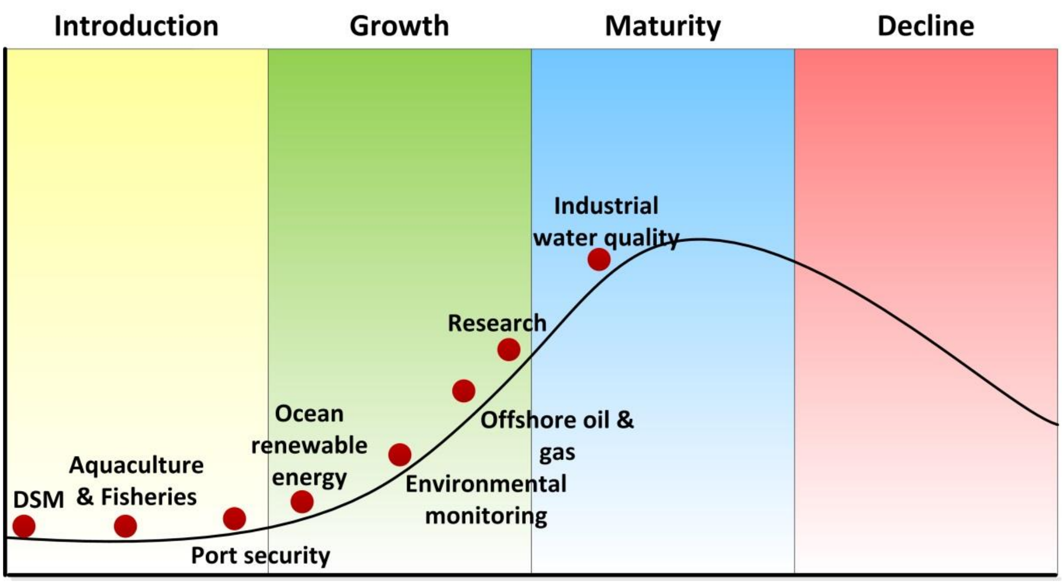
The use of sensors to reduce the risk of terrorist attacks is not legally mandatory. Port authorities are only required to carry out underwater monitoring activities in order to measure noise levels. These noise levels mainly relate to port activities, e.g. mooring and loading/unloading activities.

3.3.10 *Synthesis: position of each sector in terms of sensor use*

Based on the market descriptions above it is possible to place the different sectors in the product life cycle graph. In the figure below the different sectors are plotted. It should be noted that only the level of sensor use per sector is considered, irrespective of the development of the sector itself. For example the sector of fisheries obviously is a long established sector, however with regard to sensor use it is still in its introduction phase.

As the figure shows in most sectors the use of sensors is not very advanced yet. In hardly any of the sectors the use of sensors has reached its maturity, with industrial water quality management as the only exception.

FIGURE 3-7 THE MARKET PHASE FOR EACH SECTOR IN TERMS OF SENSOR USE



Source: Ecorys (2014)

The following table provides an overview of the main research topics (sensor improvement demands) from each market sector, sorted by type of aim (industrial/economic, legal or R&D motive) to use sensors.

TABLE 3.2 MAIN R&D TOPICS AND INDUSTRIAL/ECONOMICAL MOTIVE FOR SENSOR USE PER MARKET

Aim / Market	R&D	Industrial / economic perspective	Legal
	Sensor aim from the perspective of market sectors		
Monitoring of environmental quality	*Measuring more parameters *Ensuring compliance with MSFD	-	Fulfil general obligation to monitor quality of marine environment
Offshore oil & gas	*Sensor stability *Data transmission *Data measuring options	*Prevention of oil spills *Improve maintenance	Reduce effect of activities on mammals and fish stock
Industrial water quality measurements	*Focusing on sensor size	Optimize business operations	Standards on fresh water quality
Oceanographic research	*Measuring more parameters *Accuracy *Energy consumption *Anti-fouling	Provide information to oil & gas industry, maybe other sectors upcoming	General environmental monitoring
Fisheries	*Compact systems not hampering activities *Easy downloading of data	Better monitoring of quantity and quality of fish stocks (to better negotiate quota)	-
Aquaculture	*Operational capabilities of the sensors *Compact systems not hampering activities	Better monitoring of quantity and quality of animals and crop	Being in compliance with general health and safety rules
Ocean renewable energy	*Power requirements (no cable) *Data transmission	*Improve maintenance process *Collect operational data	-
Deep sea mining	*Measuring at deeper depth *Energy consumption	*Monitoring equipment *Sea floor information	-
Port security	Detecting divers	Lower insurance costs as ports become better protected	Obligation to measure noise pollution in port area.

3.4 Assessment of the role of sensors in different markets

Above the current market development phase and market structure is described. The descriptions focused on the adaptation rate of sensors in the different markets. Although the use of sensors in a specific sector can be relatively new, the market itself can be well-established. For example, fishing activities take place for many centuries and modern fishing techniques are used for several decades already, However the use of EAF or single sensors is still very new to the sector, but in the future could offer many opportunities for sensor manufacturers and service providers.

To assess the potential role of sensors in the different markets two indicators have been defined. First of all it is important to know what the current size of the specific market itself is today and secondly what it will in the coming years. Based on these figures it is possible to estimate whether the market itself is growing, stabilizing or declining. It is assumed that the uptake of sensor use is larger in growing markets than markets in decline. Both current size of most markets and their size in 2020 have been estimated in a recent study carried out for DG MARE[23].

Second the current use of sensors needs to estimated. No complete figures are available for this, but based on interviews held and the market descriptions it is possible to assess the intensity of sensor use. In some of the markets sensor use is non-existent, while in others sensors are already commonly used. In the latter markets it is expected that the role of sensors will not increase tremendously. The role of sensors is assessed qualitatively and a distinction is made between a limited, an average and a large role.

The table below shows an assessment of the size of the markets distinguished. Both the current size and the forecasted size in 2020 are presented. Also to the role of sensor use in the different sensors is assessed, both the current and 2020 use. The role of sensors use is a qualitative assessment.

TABLE 3.3 SECTOR SIZE AND ASSESSMENT OF THE ROLE OF SENSORS IN EACH MARKET SECTOR

	Size of the sector[24]		Role of sensors in the sector	
	2010 (value added € bn)	2020	2010	2020
Monitoring of environmental quality[25]	4	10	oo	ooo
Offshore oil & gas	120	95	oo	ooo
Industrial water quality measurements	?	?	oo	oo
Oceanographic research	4	10	oo	oo
Fisheries	9	7.5	o	oo
Aquaculture	0.5	0.7	o	oo
Ocean renewable energy[26]	2.4	16.9	o	oo
Deep sea mining	< 0.25	0.3	-	ooo
Port security[27]	3,8	9,7	o	ooo

Source: Ecorys (2012)

Legend:

o limited role

oo average role

ooo large role

23 Ecorys (2012)

24 Ecorys (2012)

25 In the Blue growth study no difference between monitoring of environmental quality and oceanographic research is made. Therefore the same figures are included in the table, however the figures per sub activity will be lower.

26 Both offshore wind as well as ocean renewable energy (wave, tidal, OTEC, thermal etc.)

27 Figures include all monitoring activities related to human activities and do not specifically relate to monitoring in ports. Activities included are the 'Traceability and security of goods supply chains' and 'Prevent and protect against illegal movement of people and goods'

4. SUPPLY SIDE – VALUE CHAIN

In this chapter we aim to produce an analysis of the value chain of environmental monitoring. Further we analyse the compilation of stakeholders that perform the different activities on the value chain and elaborate on how the set-up of the European industry compares with that of other regions. Finally a SWOT analysis of the European marine sensor industry is conducted to assist in the assessment of its competitive position.

4.1 Value chain

4.1.1 *The value chain concept*

As is the case for many industries, the European marine sensor manufacturing industry is not a stand-alone industry. This meaning that, in order for the industry to function, it requires inputs from other industries to produce its products which in turn are inputs for other industries as well. The chain of products goes on until products that are delivered to end users are reached. This concept has been introduced by Porter and was further developed by Anthony and Govindarajan[28] as a product's value system. The value system spans from the production of raw materials to the delivery of final products where only a given amount of profit margin is available to be distributed amongst all organisations that take part in the value system. This profit margin consists of the difference in the price the final user is willing to pay and the sum of all costs incurred for the production and delivery of all intermediate products and services.

Therefore, it is important to analyse the competitiveness of the European marine sensor industry without isolating it from the context formed within the whole value system of the final products, which in this case are marine environmental monitoring activities. The stakeholders performing the activities within the value chain might use their market position or negotiation power to obtain a larger share of the profit margin, or they might choose to cooperate to improve efficiency and reduce costs. The value chain analysis of the European marine sensor industry needs to take into account the whole value system in which environmental monitoring sensors are used. Such an analysis would, in the case of the industry at stake, include:

- An analysis of the marine sensor manufacturer's own value chain – which are the activities performed by marine sensor manufacturers to add value to the final product.
- An analysis of the value chain of the manufacturers' customers – how do marine sensors fit into the value chain of the industry's clients.
- Identification of potential value added for the customer – how can the industry's products further add value to the customers value chain (e.g. lower costs or higher performance)

The value chain analysis is a useful analytical tool in pursue of a sector's competitive advantage. By pinning down the activities different stakeholders perform within the overall value chain of the final product and understanding what the value added for final users is, the room for exploiting the competitive position of the marine sensor manufacturing sector, as well as the potential for cooperation with other stakeholders of the value chain can be identified. In practical terms this leads to two lines for achieving a competitive advantage for a product, these are by pursuing:

- **Cost reduction:** By better understanding what are the final product requirements, the cost that do not contribute to this can be reduced in order to achieve a competitive advantage
- **Product diversification:** Mapping the activities the enterprises of the sector perform and assessing where manufacturers are better capable of focusing to add value to the final product makes it possible to concentrate their efforts to activities where they have a competitive edge.29

[28] R.N. Anthony and V. Govindarajan, 1994, Management Control Systems, Homewood Ill.: Irwin.

[29] Institute of management accountants, 1996, Value chain analysis for assessing competitive advantage, Institute of Management Accountants

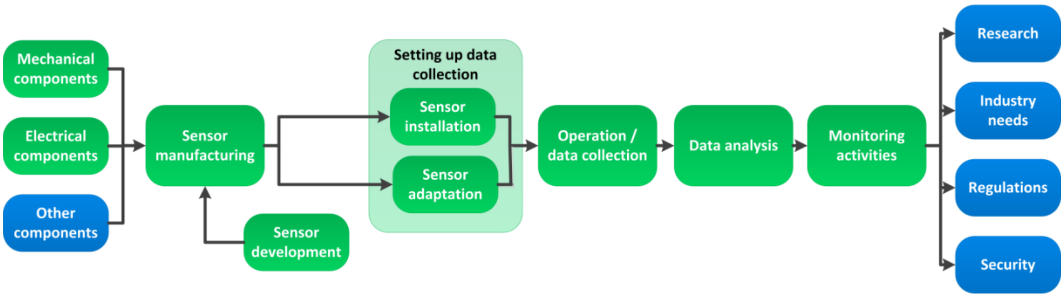
4.1.2 *Activities of the value chain*

An important first step in investigating the above is to pin down the activities that add value to the final product of environmental monitoring activities and map the participation of the involved stakeholders regarding these activities.

Figure 4-1 shows the different activities within the sensor value chain leading to the provision of environmental monitoring activities. The aim of this figure is to identify the position of sensor manufacturing within the greater picture of environmental monitoring services, with marine sensor manufacturing comprising a activity of the whole value chain.

The activities described in this value chain range from the mechanical and electrical components supply, needed to produce sensors to the actual monitoring activities carried out. The activities on the value chain are performed by different stakeholder groups, often with overlap among them. Most of the actors do not carry out one single activity, but cover multiple different activities; however the number of value chain activities each stakeholder carries out may vary depending on the aim and client of the end product. A significant exception is that of the suppliers of components who usually limit themselves to supplying different components for manufacturing the sensors, aside from other industrial applications.

FIGURE 4-1:VALUE CHAIN OF ENVIRONMENTAL MONITORING SERVICES



Following the marine environmental monitoring value chain as built after the findings of the literature review and the interviews with selected stakeholders, the activities performed adding value to the end product are briefly described hereunder starting from the end-product and going backwards to the basis of the value chain.

Environmental monitoring activities

Marine environmental monitoring services are the final product of the value chain. This activity refers to actually reaching conclusions to answer the aim of the activity, as defined by the end user, after assessing the collected data. The end-user may vary from a private enterprise opting for optimisation of its processes, to a public administrative body aiming to monitor the quality of its water reserves or to research institutes performing marine (but not only) research. As explained in the previous chapter, the aim of the monitoring activity is to define the setting of the activity and whether there is value added to achieve mostly in cost reduction or product diversification. In short the findings of the previous chapter indicate that emphasis is placed on cost reduction when the aim of the monitoring activity is legal. For research aims, there is a preference to diversified products that, beyond lower costs, also bring in capacity to monitor more parameters in different environmental conditions. Finally industrial aims focus also on product diversification by means of increased robustness and reliability of systems without however totally neglecting the cost element.

Data analysis

Data analysis refers to the assessment of the collected data from the operation of the marine sensors to calculate a defined set of environmental indicators. This activity may rely on data collected from marine sensors or a combination of these data with data produced from other activities. An important input to this activity also concerns the development of software tools/portals for the storage, analysis and presentation of the collected data, or tools for fulfilling reporting obligations of marine observation data. A major characteristic of this activity is that it does not have to be performed in the vicinity of the location of the measurements but can be performed in any location as long as the employment of skilled personnel is provided to analyse and interpret the collected data and calculate the needed set of indicators.

Operation of marine sensors/data collection

The obvious prerequisite to the data analysis activity is the activity of data collection. This refers to the actual operation of the marine sensors, their maintenance and logging of their measurements. This activity may be performed by the same actor that analyses the data, or might be performed by a different actor that has the operational capacity to collect the data and maintain (if necessary) the sensors at the location of the measurements. It is an activity requiring technical capacity to interact with the sensors and retrieve the collected data. In some cases the transmission of data is done automatically through a wired or wireless connection, however in case the obtained data are of significant volume or the sensor operation is in remote environments a regular physical interaction with the sensors is required. In some cases, data retrieval and sensor maintenance can consist a significant part of the overall costs. Such is the case for environmental monitoring in remote environments such as the Arctic. An additional consideration regarding the operation of sensors is their maintenance. Especially for long term monitoring, sensor robustness and their capacity to handle bio-fouling is of paramount importance.

Design and Setup of data collection

This is the activity that bridges the gap between obtaining a sensor after the manufacturing activity and actually operating it in the environment of choice and performing the data collection process. This refers to two sub-activities: i) adapting -if necessary – the configuration of the sensors to the requirements of the specific monitoring assignment by applying modifications to the sensor; and ii) installing the sensors in the monitoring environment physically and operationally; as well as the design of these processes. Physical installation refers to either mounting the sensor on the location of measurements or adjusting it on a monitoring platform (buoy, glider, observatory etc.). Operational installation refers to software configuration and arranging the interoperability of the sensor with the rest of the monitoring equipment including the possibility of building infrastructures that allow sharing observation data (e.g. sharing data between observatories. This activity requires good knowledge of sensor hardware and software as well as a good understanding of the data collection activity goals and challenges.

Sensor manufacturing

The activity of manufacturing sensors is usually regarded as the core activity of sensor manufacturers. Performed in locations far away from the site of operation, sensor manufacturing makes usually use of a supply chain spanning beyond the region where the manufacturer is located. During this step of the value chain, the sensor components and other materials are compiled, with the input of highly specialised skilled labour, into operational sensors. Depending on the aim of the application, prototype sensors might (and they quite often are) need to be further developed or adjusted to meet the specific requirements of clients as deriving from the aim of the monitoring activity.

Sensor manufacturing calls for good assessment of the market needs regarding sensor requirements in order to drive the production of sensors with a value for end clients. Thus a good investigation of where added value lays in each market segment is required. Additionally the marketing, after-sales service and product distribution functions are important factors siding the success of sensor manufacturing.

Sensor development

Being a market mostly in a pre-maturity stage the marine sensor market has not yet achieved full development of its products. There is a constant call for development of new sensor products that can measure additional parameters, meet with stricter requirements and have lower purchase and maintenance costs. Therefore still a large amount of resources (relative to the market size) is applied in research to further develop new or existing sensors. Highly specialised scientists are required to perform the necessary research in an urge to keep up with the growing market and its increasing requirements. The activity of sensor development, depending on its focus can aim both in cost reduction by reducing costs not only of sensors but also the costs they induce during their operation (data transmission, power requirement etc.), as well as in product diversification by either producing more robust and reliable versions of existing sensors or by developing sensors capable of measuring additional parameters (or provide with more detailed measurements).

Components supply

The input of components to sensor manufacturers is the very first activity of the value chain and can be a critical one. Some of the components that are needed for manufacturing marine sensors can be highly specialised electrical or mechanical parts. Especially for highly specialised components, the production process depends on only a few qualified suppliers. These suppliers may not perceive themselves as a part of the environmental monitoring value chain, at least not more than of the value chains of other industrial applications their products are used for. The link between specialised suppliers and sensor manufacturers is a crucial one for the production of marine sensors as it can consist a bottleneck when the production of sensors within a limited timeframe is required. This dependency comprises a risk identified by sensor manufacturers who are trying to abate it with a number of approaches.

4.2 Stakeholders and their value chain roles

The maturity level of most market segments, being either in an introduction or a growing phase for sensors sales leads to a less steady environment regarding the definition of stakeholder groups and the activities of the value chain they perform. While a more generic approach to the definition of the stakeholder groups, based on their core activity and the area they position themselves on the value chain; a rigid definition of the boundaries of the activities performed by stakeholder groups is not applicable to all actors. Moreover, as the market segments gradually reach maturity over time, a redefinition of the actors’ scope of activities is expected with them re-deploying themselves according to the business models adopted in an effort to attract maximum profit for their value added.

That said, in the value chain of the marine environmental monitoring services four main stakeholder groups have been distinguished: i) sensor developers; ii) sensor manufacturers; iii) service providers and iv) clients / users of sensors. Beside the four main stakeholder categories also the functions of component suppliers, software suppliers and sensor integrators can be identified. Regarding the first two, these actors often have a way broader scope than supplying components to marine sensor manufacturers and do not position themselves in as market specific actors.

On the other hand, actors performing the function of integrating the sensors to the monitoring environment and setting up the data collection process usually belong to one of the main stakeholder groups. Although taking up a distinct specialised part of the value chain, these actors cannot be easily regarded as a distinct group (although due to their limited numbers) but rather as actors whose behaviour slightly deviates from the main stakeholder group they belong to.

Therefore the main stakeholder groups in the marine environmental monitoring value chain that are going to be examined in this section are:

- Sensor manufacturers
- Sensor developers
- Monitoring service providers
- Users / clients

4.2.1 *Manufacturers*

The stakeholder group of European marine sensor manufacturers is quite diverse and consists mainly of (very) small enterprises. The norm for these actors is to make use of various components provided by a number of suppliers to manufacture marine sensors with the input of highly skilled labour. Actors of this group usually produce a small number of sensors and most of them focus on one sensor type, e.g. passive acoustic or optical sensors. This high specialisation leads to decreased competition in the market sub-segments where these actors operate as there are no more than a handful of competing actors to provide with sensors according to the specifications needed. The perceived competition is quite low when specific sensor qualifications are regarded, however there are quite some potential competitors that produce the same types of sensors and have just not developed directly competing sensor models.[30]

Although the manufacturers themselves indicate they have not many competitors (based on the exact sensors specifications) there is quite some competition within the market.

Although future market prospects for the manufacturer group seem bright, the volumes of sales every year for each of them do not usually exceed some tens of sensors. The lack of well established standards for the application of sensors and the still evolving market requirements for most segments leads to the low standardisation of the products while most manufacturers are developing variations of their prototype sensors according to the needs of each individual client. This process requires large amounts of resources being deployed in sensor R&D which in some cases can constitute the majority of the costs to produce a sensor.

A large number of sensor manufacturers expand their activities further from sensor development according to the ad hoc client needs. Eventually, there are cases where manufacturing actors set up the sensors in the monitoring environment, collect and analyse the collected data. There are even cases where the manufacturers take up the whole value chain delivering environmental monitoring activities to the end users in an attempt to gain references and open the market as is the case for some very new and innovative products.

On the other end of the value chain, manufacturers realise the weakness generated by their dependence on suppliers of highly specialised components and are working towards securing their position in that aspect. First, manufacturers invest in the robustness of their supply lines by building long-term relations with components suppliers with a preference to suppliers located in the same region or country, If that is not possible, then a European supplier is preferred to one based on another continent. Additionally some manufacturers have gone further to vertically integrating part of their own value chain by internalising the production of some or more of their most needed components in an attempt to avoid risks and minimise lead times in delivery.

Overall, some actors are stretching the scope of their activities to an increased number of value chain activities trying to fulfil client demand for a one-stop-store. Others are narrowing down their range of activities and specialise by outsourcing most activities and only concentrating on their core activity (sensor manufacturing) where they believe they can apply their competitive edge to achieve higher added value.

4.2.2 *Developers*

Sensor developers are actors active in R&D related to marine environmental sensor development. While a considerable part of the sensor development is performed by the sensor manufacturer stakeholder group, there are still large parts of the R&D activity that are handled by independent organisations, usually being part of a university or research organisation (oceanographic institutes) which besides sensor development are also active end-users of the sensors. Europe counts about a dozen of large oceanographic institutes which are quite active in the market. Besides, several universities and smaller institutes are active as well.

These actors may come in agreement with sensor manufacturers to jointly or further develop sensors. Their commitment to further developing marine sensors is also backed by their interest in improving sensor performance to facilitate their own research activities. The current focus of sensor development is set in improving sensor performance, e.g. power requirements, stability and sensor interoperability.

Research organisations and universities do not limit their activities within the value chain to only sensor development. Being experienced end-users of sensor systems, actors of this stakeholder

[30] Highlighting this fact is the interview finding that there are usually more than 10 sensors capable of measuring the parameters at stake, but after further checking the whole set of requirements, this is limited down to just 2-3 sensors that yield a good value-for-money for the specific application.

group often extend the scope of their activities within the value chain beyond merely being an end-user. Either for their own use, or as a service to other end-users, they may take control of the whole value chain after sensor manufacturing, setting up the data collection system, performing the data collection activity and even analysing the gathered data and performing the whole environmental monitoring service. In case the aim of the service is own R&D, the actors of these sectors decide to outsource or not part of the activities depending on budget and skilled labour availability.

4.2.3 *Service providers*

The third identified stakeholder group is that of service providers. This stakeholder group consists of an increasing number of (currently) SMEs that take over the task to bridge the gap between sensor manufacturers and end-users filling up for the lack of willingness to expand the scope of activities of manufacturers and that of technical capacity of end-users, usually offering the operational capacity that both of them lack. These enterprises have developed to partially replace research institutions that used to cover the same gap, but with a more applied and business-oriented approach. The actors within this group may offer services ranging from design, set up and operation of the data collection activities, to data analysis, development and supply of (customized) software to enable the sharing, analysis and visualization of collected data and complete environmental monitoring services even as a part of a broader-scoped assignment e.g. environmental studies or impact assessment studies.

The service providers are often the owners and integrators of the platforms and sensors and usually take up also the role of sensor integrator. They usually do the methodological design of the data collection process, choose the equipment needed and might buy them and lease / rent to their clients or they might just offer their services should the client wish to obtain ownership of the hardware. The exact scope of their activities ranges based on the capacity and willingness of end-users to take up activities earlier in the value chain. It is often that end users just buy the final datasets from the service providers.

Service providing is a rather new type of role in the marine environmental monitoring value chain and most companies that take up this role, with a few exceptions, are SMEs. These enterprises might be agencies that perform environmental studies and not even have marine environmental monitoring as their core business but perform it as part of their service portfolio to their clients. Their clients are the actual end-users of the marine environmental monitoring activity.

Amongst service providers there is a growing amount of competition, since market growth attracts new actors in the market. However competition can be limited when the scope of the monitoring activity is quite specific and, dependent on the market segment and the country of the application.

Some service providers are solely focused on data collection, while others also carry out analysis and monitoring services. Finally, a significant factor influencing the status of competition is that of national legislation constraints. This can be the case for larger country markets with specific environmental legislation, where already established local firms have a head start compared to foreign companies. A key challenge that service providers face is to find adequately skilled personnel that would be ready to work after the conclusion of their university studies.

4.2.4 *End Users*

The last category, that of end-users, is a very diverse group of stakeholders. End-users are the ones using the results of marine monitoring activities. These can be private companies, public authorities, local governments, research institutes, NGOs or associations (professional or of other kind). Practically it can be any type of entity that is interested in activities of the market areas described earlier.

The end user group is the one to set the requirements for the monitoring activity which in turn are driven by the aim of the monitoring exercise which can be research driven, part of industrial optimisation or a legal obligation. Usually, the end-users group might be subdivided along this division of their aims however it might be the case that the same end-user performs with a different motive in the case of different exercises.

In accordance to the aims of the environmental monitoring activity, end-users tend to tune their approach and selection criteria for the service at hand as well as their involvement in the value chain activities. When meeting legal obligations to monitor environmental conditions is the case, end-users will place a high value on costs (accounting for all purchase, maintenance or operation) as long as the minimum monitoring requirements are met. Additionally they would be prompt to abstain as much as possible from taking on activities of the value chain. In this subdivision are usually public and local authorities or enterprises and professional associations obliged to monitor their environmental performance.

Should the motive be that of improving business operations, end-users are found much more willing to take–up a role and control of the value chain activities. This is due to the environmental monitoring activity being then closely related to their performance on their core activity, in most cases influencing their profitability. In which case, end-users value tested and robust sensor systems placing less weight on the costs involved as long as the monitoring of their performance can lead to clear economic benefits. This category consists predominantly of private enterprises which see an efficiency gain in monitoring environmental parameters with the use of sensors.

Finally, in case of a research-driven need to use sensors, end-users are usually more focused on the attributes of the sensors, their reliability and capability to measure the necessary parameters with a detail sufficient for their research needs. Despite the limited budget compared to users of the previous subdivision, this stakeholder group is quite demanding on the specifications of the sensors used. Researchers can have high technical knowledge of the sensors used and tend to take over also the setting, adjustment and operation of the monitoring framework, as well as the data collection and analysis tasks. Moreover, when existing sensors do not meet the exact needs of their monitoring activity, the end-users with a research aim might even put effort in developing them to reach the required standards.

TABLE 4.1: GOALS OF VALUE CHAIN ACTORS IN RELATION TO THE AIMS OF SENSOR USE

Aim / Stakeholders	R&D	Industrial / economic perspective	Legal
Goals of value chain actors in relation to the aims of sensor uses			
Sensor developers	*Less power consumption *Measuring more parameters *Reliability and robustness	* Reliability and robustness	*Sensor cost reduction
Manufacturers	*Measuring more parameters *Operational in adverse environments	*Prove sensors with references *Promote sensor -using mentality	*Sensor standardisation
Services providers	*Offering wide range of sensors and platforms. *Provide operational capacity	*Promote monitoring mentality *Integration of sensor platforms *Interoperability and data transmission	*Standardisation of monitoring requirements
Users	*Measuring more parameters *More reliable/precise measurements	*Improving operational processes and cost saving	*Fulfilling legal obligations for environmental monitoring

4.3 Global industry

Regarding the global marine environmental monitoring sensor manufacturing industry, Europe and North America are the home of the majority of sensor manufacturers. This has been the case as environmental awareness has been larger in the past in these parts of the globe, leading to sensor producers being founded here. Nowadays, a small number of actors located in Western/North Europe, the United States of America and Canada cover global demand for marine optic and passive acoustic sensors.

Competition to the European SME manufacturers currently comes from U.S. and Canadian enterprises. The North American market contains a couple of larger actors (*Sea-Bird Electronics Inc.* and *Teledyne Technologies*) that operate along most market segments and some additional SMEs usually operating in niche market segments. In contrast to the European SMEs that are fairly focused on marine sensors production, forming an important part (though not necessarily the largest) of their business, the larger North American Enterprises have integrated sensor production in a larger set of products and services. This horizontal integration of the value chain has been usually the result of these larger organisations taking-over companies that have a similar or relevant product line.

Usually marine optical and passive acoustic sensors are integrated in sensor platforms that contain also other types of sensors. One of the most broadly used sensor types is the salinity-temperature-depth (STD) sensor which is used in nearly all marine environmental monitoring activities to log the values of these basic parameters. The STD sensor market is nearly monopolised by a single U.S. company, providing it with a competitive edge when clients consider also the purchase of other sensors.

Overall, being part of a larger organisation can make marketing of sensors easier for North American companies securing recognisability of manufacturers' products by using a well-established brand name.

Another advantage of the North American manufacturers is the fact that the United States market is relatively inaccessible to European manufacturers due to the strict tender requirements set for imported sensors. It is considered that these requirements are set to discourage foreign enterprises. This limits the European manufacturers from competing effectively within the North American market while the opposite is not the case for the access of North American sensor manufacturing enterprises to the European market. European manufacturers try to partner with North American actors to overcome this obstacle.

Sensor producers in other parts of the world have not yet evolved. However, as environmental awareness is raising rapidly in middle and lower income countries and environmental legislation is established, the need for marine environmental monitoring activities is expected to increase globally with a big part of that increase coming from the faster developing countries. It can be then anticipated that companies that produce marine sensors will appear also in middle and lower income countries. European manufacturers anticipate that these enterprises might probably attempt to secure a piece of the global market by producing lower cost products, emphasising on local cheap labour, similar to the established industrial production model currently applied in East Asia in other technology sectors. However it would not be before a number of years, due to the necessary product development, that this would pose a threat to European and North American enterprises.

4.4 European industry

As mentioned also earlier, the European sensor manufacturing stakeholder group consists to a large extent of SMEs. These companies consist, to a large extent, of university or research institute spin-offs or start-ups and are focused on specific sensor types each. They are located mainly in a small number of countries of Western and Northern Europe (Germany, France, UK, Italy and Norway).

As discussed in the previous section, the European manufacturing firms, in contrast to their North American counterparts, either tend to try and expand vertically on the environmental monitoring services value chain rather than horizontally, or they tend to pursue growth through specialising in the activities they perceive to have a competitive advantage.

The focus of European manufacturers can be even more specific than focusing on sensor types, concentrating on specific variations of a sensor type. Therefore their perception of the market may many times concern the specific sub-segment where their product is applicable. Regarding those niche market segments, the competition is usually limited consisting of 3-5 companies that produce sensors meeting these requirements with approximately half of these being European ones and the rest originating from North America.

Sales range from a couple of tens to a couple of hundreds of sensors per year per manufacturer; especially their sales in Europe are heavily determined by the volume of funds committed to research. Another large market for European manufacturers is that of East Asia which for some can be even more important than their home market. The general perception among interviewees is that the East Asia market is more generous making it a lucrative market to get involved. In their attempt to secure larger market shares and establish themselves in the different growing geographical markets, European manufactures seek exposure and cooperation with other actors in conferences and other networking events (including the participation in consortium projects like NeXOS).

Since the perception of the sensor market among European sensor manufacturers is disaggregated to the level of specific sensors it is not easy to produce an exact estimate of their overall share. Regarding the European sensor market, the estimation of European manufacturers regarding their market share is that they obtain a considerable portion of the pie starting from 20% and in some cases reaching over 60%. Regarding the global market, estimates of European manufacturers start from a few percent and can reach to more than 50% especially in niche markets and depending on the market at stake. However these figures depend on each specific market segment examined. In assessing the market position one should also consider the inaccessibility of the market of the U.S.A.

4.4.1 ***Manufacturers and links with other stakeholder groups***

As has already been described in the previous section, the companies of the European sensor manufacturing industry do not appear to adopt a harmonised approach to positioning themselves on the environmental monitoring services value chain. Some of them aim at specialising in their core activity of manufacturing sensors, while others tend to expand their scope to meet the demands of their clients. This diversification in approaches is a consequence of the youth of some market segments which have not been yet totally developed, in combination with the specific characteristics of some niche sensor markets.

Companies that are established and operate in more mainstream markets with higher selling volumes and applications better explored, tend to limit themselves to producing sensors, relevant R&D and after-sales service. This is facilitated by the development of the intermediate stakeholder group of service providers that take over the rest of the value chain activities leading to the end-user. For industrial and some research applications it is also possible that the end-user is willing to take control of the rest of the activities of the value chain.

On the other hand, companies that operate in niche or less developed markets come across the necessity to provide the full package of value chain activities to their clients. This is due to the fact that in these market conditions there is usually limited knowledge available (or willingness to develop it) to end-users or service providers on operating these sensors.

To summarise, the aim and development level of the market segment as well as the availability of stakeholders to take-up tasks on the value chain lead to the final relation of manufacturers with other stakeholders. The availability and cooperation with middle stakeholder layers can free-up highly needed capacity to be devoted on the core business of sensor manufacturing. This role can also be performed by the hybrid group of sensor integrators, as long as there is limited or no conflicting interest in matters of competing sensors. However, the latter should not be the case in niche market segments.

On the other hand, when examining the relationship with stakeholders upstream the value chain, the European manufacturers' position is threatened by the near-monopolistic status of non-European manufacturers operating in neighbouring markets (e.g. CTD-STD-sensors) who with their market position gain negotiating power. Moreover, the scarcity of specialised components manufacturers, especially if based outside Europe, can also threat the position of European manufacturers. The requirement to pay up in front for components, in combination with payment after the delivery of the sensors or even delayed payment causes a financial gap for manufacturers, which is not always easy to cover. Additionally, for intercontinental component shipping, the time needed for delivery is added to the product production time which is anyway squeezed enough by the delivery time requirements of clients.

4.4.2 *SWOT of European industry*

In this section a SWOT analysis of the European marine monitoring sensor manufacturing sector is provided. This section aims to highlight the strong and weak points of the sector as well as identify the opportunities and threats affecting sector viability due to external conditions.

TABLE 4.2: SWOT ANALYSIS OF THE EU MARINE SENSOR MANUFACTURING SECTOR

Strengths	Weaknesses
• Developed local market • Good global and home market share • Penetration in niche markets • Established cooperation with developers • Present in activities of all monitoring aims • SMEs appropriate for delivering innovative products in a growing (not settled) market	• Inaccessibility of US market • Lack of product standardisation • Low activity specialisation • Difficulty of SMEs to network efficiently • Partial (but in-depth) market view • Production on demand leads to high lead times • Lack of skilled personnel with hands-on experience and ready to apply knowledge • Need for clarified business models (specialisation vs integration on the value chain) • Financing production can be a challenge (sometimes)
Opportunities	**Threats**
• Advanced marine/maritime cluster of Europe • New growing geographical markets • Growing and promising market segments • Raising environmental awareness • Relative availability of research grants • Availability of higher education labour in home market • Establish relation with industrial end-users (through research grants, conferences, research institutes, networking events etc.) • Pioneering research institutes in local market	• Prospect of low cost competition from lower income countries • Increasing need for scarce skilled labour to achieve growth • Lack of sensor-using mentality (understanding of benefits) • Varying national legislation • Near-monopolistic status of actors pursuing horizontal integration of value chain elements • Dependency on unstable research budgets • Burdensome grant application/tender procedures

5. DRIVERS AND CHALLENGES

5.1 Technical challenges

Based on the previously presented market descriptions and the interviews held a picture emerged that some research topics are not specific for a particular market sector, but that several topics occur in almost every market and are applicable to the different types of sensors, i.e. optical sensor systems, passive acoustic sensor systems and EAF. By resolving these overall technical challenges sensor use in general can be stimulated. The most important challenges faced by users of the sensors in the different market are:

- Power requirements
- Stability
- Standardisation
- Interoperability
- Anti-fouling
- Data transmission

Each of these challenges is discussed below.

5.1.1 *Power requirements*

The first challenge relates to the power requirement of both the sensor and the platform. Power requirements are important for sensor systems that are away (at sea) for several months or years in a row. These systems do not have the opportunity to recharge easily, especially when the system is used in remote areas, e.g. the Arctic, or at great depths. To ensure that the systems can stay away for such long periods of time, energy regulation is important. Sensors should not waste energy on activities that do not contribute to data measurements.

The power requirements also influence the data transmission. Sending of large data sets requires much energy and therefore most systems only sent a sample of data directly via satellite to shore. All other data are stored on board the platform and these data are downloaded once the platform is near shore again.

In the online questionnaire 65% (11 out of 17) of the interviewees indicated that power requirements are of ‘high importance’ or ‘extreme importance’.

5.1.2 *Stability (incl. reliability and robustness)*

A second technical challenge mentioned is the stability of the sensor. Marine sensors are operated at sea and the conditions can be rough. Sensors often wobble and are not able to measure adequately. If a sensor is moving too much all data measured become unusable. Therefore the measuring gear should somehow be stabilised. The housing of the sensor might be wobbly, but the measuring equipment should remain stable.

If sensors become more stable the reliability will improve as well. Reliability of the sensor, both measuring accurate data and measuring when needed, is very important. With gaps in the data measured, the value of the measurements decreases as it is difficult to interpret the data sets.

Besides reliability, robustness of the sensor is important. The sensors should not be damaged easily as they often operate in a harsh environment. At great depths the sensors should be able to cope with high pressure and sensors used near shore need to be able to cope with strong currents.

Also the answers in the online questionnaire indicate that reliability and robustness are important qualifications of sensors. 94% of the interviewees (16 out of 17) indicated that reliability is of ‘high importance’ or ‘’extreme importance’, while for robustness 88% (15 out 17) indicated that this factor is of ‘high importance’ or ‘extreme importance’.

5.1.3 *Standardisation*

One of the challenges most often mentioned in the interviews is the lack of standardization. Most sensors manufactures are small companies and they produce only a few types of sensors. However quite a number of these small companies exists, and together they offer a wide range of potential sensors. Sensors are almost never used standalone, but are implemented on a platform. Each platform contains several sensors.

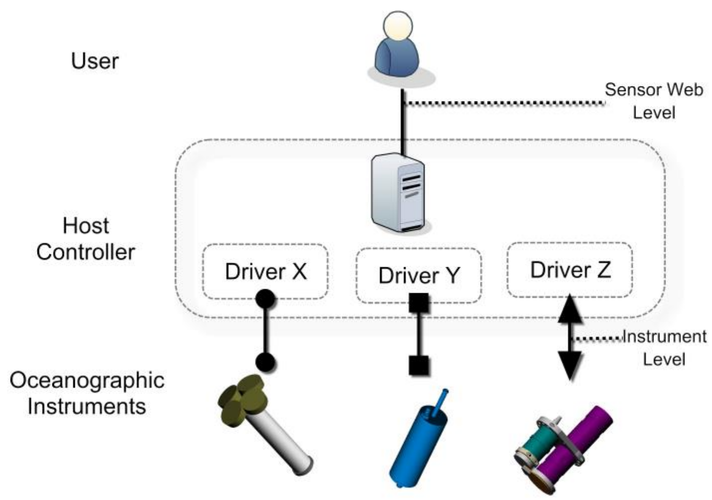
The integration of these different sensors onto the different platforms available is a costly and time consuming process. Therefore complete sensor systems are expensive as each sensor needs to be adapted in order to fit on the platform. On top of that software needs to be developed to ensure inter-sensor operability and this additional development of software increases the costs of sensor systems considerably.

For most manufacturers it is difficult to offer off-the-shelf sensors, because most clients do want to have there own specific sensors. Especially oceanographic institutes and universities want to buy specialised sensors. If sensors could become more standardised this could result in cost gains for both producers and users. The price of a whole sensor system could be reduced and this might spur the introduction of sensor systems in several markets.

5.1.4 *Sensor interoperability*

Closely linked to the need for standardization is the need for sensor interoperability. Due to the large variety of sensors interoperability can often not be realized, although sensor interoperability is vital. Currently it is difficult to use an optimal set of sensors as the sensors are not able to 'communicate' with each other or the platform. Dedicated software needs to be developed, however the new software will only be usable for the specific set of sensors and platform for which it is developed. The software cannot be used for a different set of sensors and platforms. Because the software needs to be developed for each specific set, the development costs are substantial. Increasing interoperability and bridging between interoperability gaps of legacy systems (e.g. through the NeXOS Sensor Web architecture and SEISI) will help to reduce these development costs). The following figure gives a schematic overview of the problem of sensors interoperability.

FIGURE 5-1 THE COMPLEXITY OF SENSOR INTEROPERABILITY



Source: Plocan

5.1.5 *Anti-Fouling*

Sensors are operated under water and after a certain amount of time are no longer able to measure parameters due to biofouling. Especially during productive periods biofouling (bloom) can grow rapidly and within less than two weeks the sensors are not able to provide reliable and good data.

Within the last 20 years several solutions to decrease the effects of fouling have been developed, each with its own advantages and disadvantages. As sensors often need to be able to operate for several months or even years in a row without onshore maintenance, they need to have their own maintenance system to reduce the effects of fouling.

FIGURE 5-2 IMPRESSION OF BIO-FOULING

Source: Ifremer

Biofouling frequently causes a shift in the measurements, of resulting in unusable data. The ideal solution for anti-fouling should be cost effective, have a low power requirement and should not interfere with the instruments or with the environment. The new solution should enable coastal observation system to work undisturbed for at least three months, while deep-sea observations should be able to operate for at least one year.

Although most stakeholders interviewed, especially the ones producing or using optical sensors, mentioned bio-fouling as one of the main technical challenges, the online questionnaire does not confirm this. In the questionnaire only 53 % (9 out of 17) indicate that anti-fouling is of ‘high importance’ or ‘extreme importance’.

5.1.6 *Data transmission and real time data*

The challenge of data transmission occurs mainly when sensor systems are away for long periods of time and are not near shore very often. The data collected are stored on-board the platform and only a small sample collected is sent directly to shore to be analysed. The transmission of the sample is done by satellites, which is an expensive way of sending data to shore. The remaining data are downloaded once the system is back onshore or is recharging at a docking station. Of course the data downloaded then are already a bit out-dated and cannot be used for all activities, especially to detect oil spillage etc. Closely connected to point mentioned above is the availability of real-time data. Many users would prefer real-time data in order to enable them to act immediately.

5.1.7 *Synthesis*

In the table below the seven most significant identified challenges are linked to the respective sensor (systems) examined in NeXOS. For each of the challenges it is indicated whether it is applicable to all or only some of the sensors.

TABLE 1 RELATION BETWEEN OVERALL CHALLENGES AND DIFFERENT SENSORS TYPES

Challenge	Optic	Passive acoustic	EAF
Power requirements	√	√	
Stability	√		
Standardisation	√	√	√
Sensor interoperability	√	√	√
Fouling	√		√
Data transportation	√	√	

Challenge	Optic	Passive acoustic	EAF
Gathering real-time data	√	√	

Most challenges identified both apply to optical and passive acoustic sensors systems, with optical sensors posing the most challenges to be overcome. Only a few of the general challenges also apply to the EAF, i.e. standardisation, sensor interoperability and fouling. This is influenced by the fact that the EAF system is attached to the fishing gear and is only used during fishing activities. Every single fishing action only takes a few hours and once the nets are back on board the system can be re-charged. Also the data can be downloaded directly onto a computer and sent to shore.

5.2 Framework conditions and other drivers

In this section conditions external to the marine sensor manufacturers that affect the development of their businesses are presented. These consist of regulatory and framework conditions and other drivers or trends observed that can have a significant impact on the future development of the different market segments that sensor manufacturers serve.

5.2.1 *Regulatory framework*

Since a large part of the marine sensor applications is of legal aim, it is easy to understand that the existing and upcoming regulations (in Europe and worldwide) regarding marine environmental monitoring will be of significant importance to the business prospective of the sensor manufacturing sector.

Until recently, the legal obligation for environmental monitoring in the EU was defined at a national, or even regional, level. This naturally led to great discrepancies in the means and resources applied for the obligation of monitoring environmental parameters around the continent’s waters. Moreover, the decision on the parameters to be monitored was also taken at a local level. Since the introduction of the MSFD in 2008, governments and public bodies are obliged to monitor the quality of their coastal waters and seas. Additionally, economic actors are obliged to monitor the marine environment or the effect of their activities on the marine environment. The MSFD provided also with 11 qualitative descriptors for determining good environmental status (GES). Those descriptors cover very diverse parameters and are:

1. Biological diversity is maintained. The quality and occurrence of habitats and the distribution and abundance of species are in line with prevailing physiographic, geographic and climate conditions;
2. Non-indigenous species introduced by human activities are at levels that do not adversely alter the ecosystem;
3. Populations of all commercially exploited fish and shellfish are within safe biological limits, exhibiting a population age and size distribution that is indicative of a healthy stock;
4. All elements of the marine food webs, to the extent that they are known, occur at normal abundance and diversity and levels capable of ensuring the long-term abundance of the species and the retention of their full reproductive capacity;
5. Human-induced eutrophication is minimised, especially adverse effects thereof, such as losses in biodiversity, ecosystem degradation, harmful algal blooms and oxygen deficiency in bottom waters;
6. Sea-floor integrity is at a level that ensures that the structure and functions of the ecosystems are safeguarded and benthic ecosystems, in particular, are not adversely affected;
7. Permanent alteration of hydrographical conditions does not adversely affect marine ecosystems;
8. Concentrations of contaminants are at levels not giving rise to pollution effects;
9. Contaminants in fish and other seafood for human consumption do not exceed levels established by Community legislation or other relevant standards;

10. Properties and quantities of marine litter do not cause harm to the coastal and marine environment;
11. Introduction of energy, including underwater noise, is at levels that do not adversely affect the marine environment.

In 2010, aiming to make the process of environmental monitoring the 11 descriptors of the MSFD more concrete, the GES has been adopted to provide a set of indicators for the monitoring of each of the descriptors. Although neither the MSFD or the GES regulate that sensor systems should be used, many public bodies do chose sensors as these are often more cost-effective than other solutions and are able to provide robust and concise data sets of measurements. The monitoring of the plethora of indicators described in the MSFD and GES is expected to sharply increase the need for existing/relevant marine sensors in the near future, as well as create a push for the introduction of new sensor types to better monitor the parameters that are not yet possible to monitor with the use of sensors.

Despite the above, the adoption of the MSFD and GES have not yet led to the expected increase in the use of sensors for marine environmental monitoring activities. This has been caused by the fact that the timeframe for the implementation of the MSFD has been set to 2020, in combination with the lack of funds for Member States' (MS) governments in the current economic situation.

Nevertheless, in the mid-term, with the full implementation of the MSFD, the involvement of more actors in marine monitoring activities is expected. Research institutes (such as oceanographic institutes) and universities with a focus on marine studies are expected to carry out general environmental monitoring activities, while industry actors will perform specific monitoring activities in response to their obligation to monitor and manage their impact on the marine environment. Additionally, in the future also legal obligations for reporting on environmental parameters might become relevant (e.g. delivering observation data in a standardized format to relevant national or European institutions).

Beyond Europe and North America, where both the maritime/marine clusters are well-established and strong and relevant environmental protection regulations are in place, promoting the use of marine sensors to better monitor environmental quality, the rise in environmental awareness in other countries of the world will probably lead to an increase in the demand for marine sensors and sensor services. Especially regarding the range of the faster-developing economies (BRICS, East and Southeast Asia), the strictness and detailed provisions of the adopted environmental monitoring regulations are going to draw the path for further development not only in market demand for marine sensors but also for the development of local competition.

5.2.2 *Monitoring awareness (using sensors)*

As noted in section 5.2.1, the MSFD is only defining the environmental parameters that need to be monitored (i.e. the GES). The development of the European marine sensor industry is heavily dependent on the level of awareness of the capacity of sensors to cost-effectively meet this legal obligation. Similar to that, but even more important for the future development of the industry, is the case for the industrial applications of marine sensors. The importance here lays in the potential size of this market. Since a large number of the industrial applications that occur in the marine environment are highly dependent on the surrounding environmental parameters, there is a need to consistently monitor their values. Raising awareness of industrial actors of the capacity of marine sensors to facilitate this process is an important step to increasing the market for marine sensor manufacturers.

However, raising awareness is not related only to the use of sensors, but also to the use of specific sensor models and types. For industrial actors that are not accustomed to using sensors, the European SME manufacturers are not always very visible. The case is slightly better when intermediate layers of actors are involved as they are more specialised to using sensors and probably more aware of the available suppliers. Nevertheless, the final decision on sensor selection often still lays with the end user. Moreover, there is a high industrial preference to select proven products that can showcase a number of project references. This is unfortunately not always the case with new/still developing products and therefore the need to perform pilot projects in test markets is essential for European manufacturers.

To conclude it can be stated that it is critical for the success of innovative products to develop a targeted promotion and networking approach, however this is not always easy to facilitate as an SME manufacturer. Developing the capacity to do so can be a critical factor to SMEs capturing a strong market share in the global market.

5.2.3 *Environmental monitoring research programs and availability of funding*

In recent years, a series of initiatives to systematically monitor and record environmental conditions in the seas has been developed. Specific, large-scale, research programs have been developed at a global but also at regional levels to facilitate the scientific community by providing long-term and reliable environmental datasets.

Such initiatives an initiative of a global scale is GOOS (Global Ocean Observing System) which aims to provide a global view of the ocean system via databases accessible to everyone. GOOS aims at establishing a permanent, global system for observations, modelling and analysis of marine and ocean variables to support operational ocean services worldwide. This data collection effort will need to set up a global network for data collection and will be supported by a combination of a number of monitoring systems[31]. The implementation of the GOOS system alone will require a large amount of sensors.

Additionally, up to this day, research, has been one of the drivers to market growth. Even more important is the fact that marine research has placed the need for developing new sensor types giving establishing the European sensor manufacturing industry as one of the world leaders of technological development. Through a number of European research projects (i.e. MyOcean, EuroArgo, Jerico, $FixO_3$, GROOM, EMSO, SEADATANET) as well as the European part of GOOS, the EuroGOOS (European Global Observing System), research has been a fundamental pillar for raising awareness on marine environmental monitoring capacity with the use of sensors. Some of these projects as well as other regional and national research projects have assisted in increasing demand for marine sensors, but also in creating the need to develop new sensor types.

It is important in this scope to stress the fact that while industrial and legal aims for environmental monitoring are expected to create the largest increase in demand for marine sensors, it is the funding of marine environmental research that complements the development of the marine sensor industry pushing for technological advancement of products due to the sophisticated requirements of researchers. The benefits of research funding to the sensor manufacturing industry are multiple:

- Develop the initial need for more technologically advanced sensors;
- Create a field for developing and testing innovative products;
- Assist innovative products in gaining references for future industrial applications;
- Assist in the development of informal communication channels connecting the different actors of the value chain, especially SMEs; and
- Raise awareness regarding the benefits of using sensors for environmental monitoring activities;

Therefore it should be noted that maintaining or even increasing the funding for pioneering sensor-related research can be a critical factor for sustaining the competitiveness of the European marine environmental sensor manufacturing sector.

5.2.4 *Cost of maintenance and operation*

Another factor that drives the development of the marine sensor market is that of the costs to operate and maintain a monitoring system. Especially for mainstream applications, as the costs for acquiring a sensor reduce, a driving factor for introducing sensor-based monitoring is the volume of the costs of operating and maintaining a monitoring system. Some important factors that define these cost elements are actual technical challenges that have been earlier described:

- Sensor stability (reliability and robustness);

[31] 300 Argo floats, 1250 buoys, 350 embarked systems on yachts, 100 research vessels, 200 marigraphs and holographs, 50 systems mounted on commercial ships and 200 fixed moorings,

- Power efficiency;
- Anti-fouling; and
- Data transmission

The improvement of all these factors leads to an increase in the uninterrupted period of operation for a monitoring activity performed by a sensor. Especially for monitoring activities that take place off-shore or in remote area (i.e. Arctic research) the costs of replacing or maintaining a sensor can be significant due, to a large extent, to the cost of visiting the site of operation or retrieving the platform on which the sensor is mounted.

5.2.5 *Logistics*

With the increase in maritime activities performed in large distances from the mainland, the logistics of providing the environmental monitoring service become a critical factor, not only due to the cost that they involve, but also due to the requirements for operational capacity. Gliders, buoys and research vessels etc. are operated to collect data from remote locations. The need for human resources and capital to perform these demanding tasks gives rise to the need for specialised actors that can perform them efficiently. In less developed market segments, this operation needs to either be performed by manufacturers (distracting them from their core activities) or by end-users (who might not have the technical capacity or financial interest to perform the monitoring activities themselves). Thus, the development of an efficient middlemen layer of stakeholders is a necessity to promote the development of sensor-based environmental monitoring activities when the logistics of them are demanding.

5.2.6 *Availability of skilled labour*

A specialised labour force with good technical command of the issues at stake is necessary for all stakeholders of the environmental monitoring value chain. Lack of skilled labour is not always the case for the manufacturing sector, however there are instances in which finding employees with the skills to perform some specialised parts of the work is difficult. In some countries the lack for skilled labour is a threatening issue for manufacturers; however the whole of the European manufacturing sector could be regarded as adequately trained.

However, taking a view on the whole of the value chain, it is acknowledged that other stakeholders of the value chain have more intense problems finding the right employees. Service providers for instance may be able to find employees with a suitable academic background, but there is still the need to further train them in practical issues before they can be considered ready to work. Research institutes as well might find themselves also in a lack of personnel with the right skills as some of the technical capacities necessary may need multiple years to develop. Additionally, both these stakeholder groups face the need to compete for skilled staff with more lucrative sectors (i.e. oil and gas sector), a battle that is not easy to win.

5.2.7 *Value chain consolidation*

Finally, the trend of value chain consolidation has been also observed. This consolidation might have either a vertical or a horizontal consolidation.

Horizontal consolidation is not a widely observed trend in the European marine environmental sensor industry. European manufacturers are usually SMEs for whom marine sensors are a significant part of their activities. On the other hand, the North American market can supply a couple of examples where firms are producing other sensor types, or marine equipment in general, and expand their activities to the production of marine sensors as well. This can form an endangering situation for the European sensor manufacturers as firms can choose to exploit a near-monopolistic position they have in other markets, still relevant to the end service provided to the user, to expand their market share in the marine sensor markets where the European SMEs operate.

As market segments mature, there is an increased volume of profit to be grasped. There are stakeholders that will prefer to go end-to-end on the value chain of some specific services and perform all activities leading to the end user. They aim at maximising profit by realising cost reductions through an optimal coordination between the different activities. This case of **vertical consolidation** is less often found than the horizontal one but yet the development of a couple of actors that aim to consolidate the whole value chain of specific services can have a significant impact on other actors in the same value chain, probably leading them to consider other response strategies (e.g. product diversification) to maintain their market shares.

The evolution of both these trends may be different for some market segments than others and the development of stakeholders that aim for either a horizontal or a vertical consolidation of the value chain, does not at all imply that there is no room for other actors in the field. Though, careful evaluation is needed of the competitive advantages each actor can offer to outperform developing competition.

5.3 Competitive environment assessment

This paragraph assesses the competitive environment by looking at the level and nature of competition and competitive pressures. This is done from a supply side perspective (competitor developments) and a demand side perspective (market conditions and developments).

5.3.1 *Supply side for marine sensor systems*

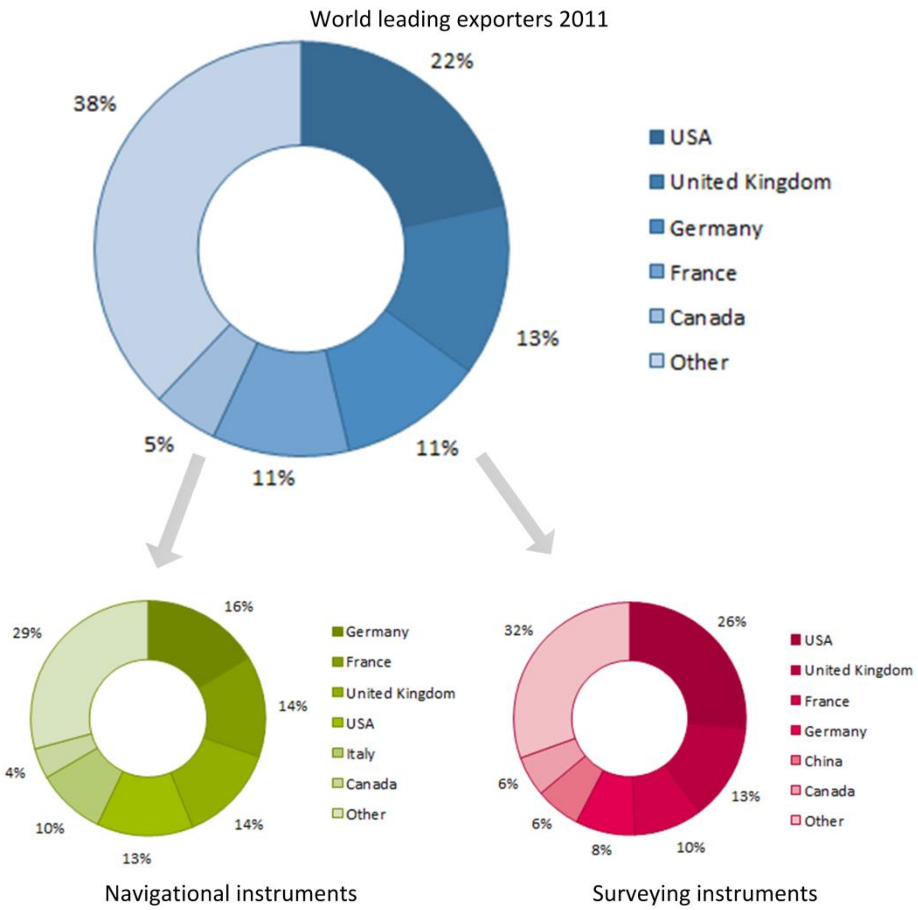
Assessing the size of the overall sensor market is difficult as the market is scattered and diverse. Especially in Europe many small players are active in the marine sensor market, each with its own set of activities. As described in Chapter 4 the market players are broadening their range of activities and therefore becoming more hybrid players in the value chain. In official statistics the marine sensor producers are not a specific group, but are part of a larger set of companies measured.

In an article published in Marine Technology (2012)[32], an estimation was made of the size of the worldwide sensing and instrumentation market. Marine sensing is part of two statistical groups, i.e. navigational instruments (HS9014) and surveying instruments (HS9015). These two groups both consist of sensor systems for both underwater and above water sensors. In the following description these statistics are used as starting point of the competitive analysis.

Between 2001 and 2011 the worldwide sensor export market has more than doubled. In 2001 the market size was € 5.8 billion ($7.5 billion) and this grew to € 12.4 billion ($16 billion) in 2011. In 2011 the navigational instruments had an export value of € 4.5 billion ($5.8 billion) and the export value of surveying instruments was € 7.8 billion ($10.1 billion). The figure below shows the shares of the leading export countries, in the total as well as within each of the two sub-markets in 2011.

32 Lee et al, (2012)

FIGURE 5-3 LEADING EXPORTERS OF NAVIGATIONAL AND SURVEY INSTRUMENTS (2011)



Source: Lee et al (2012), edited by authors

Overall, North-America and Europe are the main continents exporting marine sensors and instruments. In the total, exports of marine sensors and instruments of the main five countries (USA, UK, Germany, France and Canada) were 62% of all products produced and exported. In the subsector 'navigational instruments' these five countries plus Italy jointly exported even 71% of all products. In the sub sector 'surveying instruments' the five countries exported 62% and were accompanied by China with a share of 6%. In 2011 China was the only Asian country with a sizeable market share.

This picture was also confirmed during the interviews held. Main exporting countries are based in Europe and North America. Most interviewees mentioned that the North American companies have a dominant market position and are the preferred supplier. For European companies it is difficult to enter the North American market due to regulatory restrictions, while US-based and Canadian companies can enter the European market more easily, as they have an established name. For users, irrespective if they are oceanology or industrial players, it is important that they have used sensors of a manufacturer before. Due to the strong brand names of North American companies it is tougher for European manufacturers to compete with them.

Another point frequently mentioned in the interviews is the nearly closed US market. European manufacturers cannot easily sell their products to US-based companies as the products are not produced in the US. It has been proven very difficult from an administrative point of view for Europe-based companies to open production sites in the US and therefore they face severe problems to sell their products in the US. To strengthen the European competitive position many interviewees mentioned that the US market should open up in order to allow them to compete with the incumbents on the US market. However most of them expect that this will not happen in the near future and therefore they focus on other markets.

The companies in North America are often larger than the European players and many smaller US and Canadian companies are taken over by their larger counterparts. Contrary to the EU market that consists of many smaller players, the North American market is already dominated by some large companies, e.g. Seabird and Teledyne.

5.3.2 *Demand side for marine sensors and instruments*

The main importing countries (demand-side) are more or less the same countries as the exporting countries mentioned above. Also here China is the only exception. However the share of the importing countries is far less than their dominance as exporting countries, suggesting that many other countries are importing marine sensors systems and instruments. This picture is confirmed by the figures presented in the following table.

TABLE 5.1 LEADING IMPORTERS OF NAVIGATIONAL AND SURVEY INSTRUMENTS (2011)

Total		Navigational instruments		Surveying instruments	
USA	17.4%	USA	18.0%	USA	17.0%
United Kingdom	10.8%	United Kingdom	12.2%	United Kingdom	9.8%
Germany	7.0%	Germany	9.3%	China	8.7%
Canada	6.7%	France	8.6%	Canada	5.6%
China	6.6%	Canada	8.3%	Germany	5.3%
Other	51.5%	Other	43.6%	Other	53.6%

Source: Lee et al (2012)

During the last 10 years developing countries have become more interested in marine sensors and instruments. This increased interest can be attributed to their strong economic development of the past years and to increasing budgets. The study carried out by Lee et al. indicates the fastest growing developing countries. Overall Colombia showed the fastest growth between 2005-2011, followed by Indonesia and Russia. The value of products imported in 2011 was respectively € 111.5 million ($ 144 million) for Colombia, € 126 million ($ 163 million) for Indonesia and € 264 million ($ 341 million) for Russia.

In the navigational survey market the fastest growing market was China, followed by Russia and Hong Kong. In the surveying market Colombia showed the fastest growth, followed by Norway and Russia. The table below shows the growth per sub sector for the top-5 fastest growing countries.

TABLE 5.2 TOP-5 FASTEST GROWING OVERSEAS MARKETS IN THE PERIOD 2005-2011

Total		Navigational instruments		Surveying instruments	
Top-5	Growth	Top-5	Growth	Top-5	Growth
Colombia	452%	China	259%	Colombia	544%
Indonesia	279%	Russia	225%	Norway	264%
Russia	245%	Hong Kong	200%	Russia	249%
Brazil	158%	Singapore	96%	Indonesia	241%
Norway	149%	Italy	69%	Germany	123%

Source: Lee et al (2012)

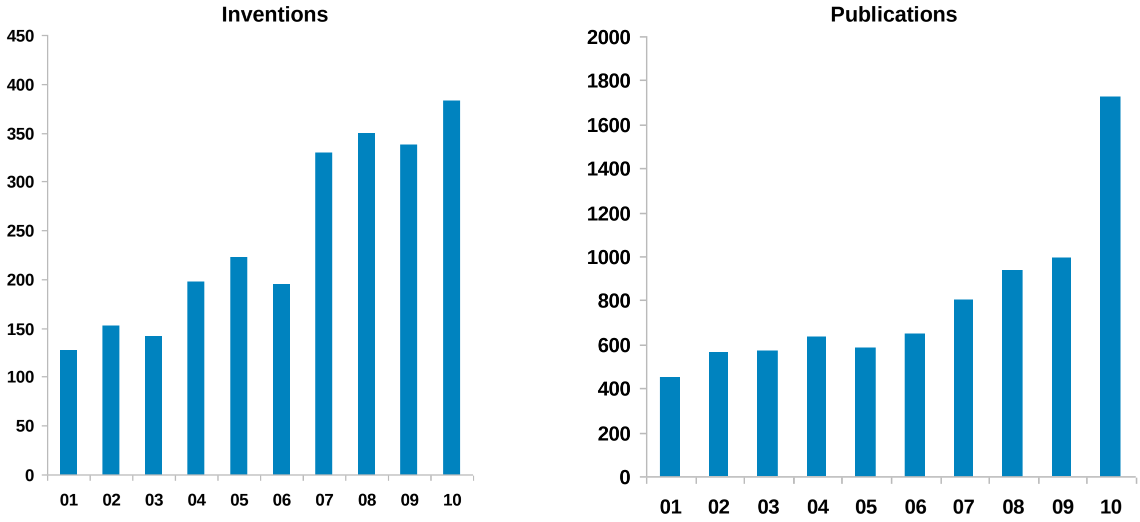
Interviewees expect that the importance of Asian countries will increase in the coming years, especially the importance of China. Asian countries have large budgets available and a growing interest in marine monitoring, especially based on industrial (commercial/economic) motivations. Besides Asian clients, European players also expect a growing market demand to come from South-American countries. The share of African countries is deemed limited as no budgets are available and interest in marine monitoring activities is limited.

5.3.3 *The EU position in research and technology patterns*

The competitive assessment of the European sensor industry can also be measured in another way. In a study carried out by Ecorys (2012) the research and technology patterns have been assessed. It is possible to measure the level of competitiveness in the number of patents requested or the number of quotations in scientific magazines obtained. The more patents or quotations are acquired by a country, the more leading the industry in that country is compared to other countries, which gives a strong basis for its competitive position.

In the period 2001 – 2010 the number of inventions (and granted patents) has increased substantially from 127 to 382. The yearly figure has almost tripled in that period, despite some yearly fluctuations as indicated by the left graph below. Also the number of scientific publications has increased, from 450 to 1724, and has almost quadrupled between 2001 and 2010. Especially between 2009 and 2010 and considerable increase is seen. Overall the importance of research and technology is important in the sector of environmental monitoring.

FIGURE 5-4 TOTAL NUMBER OF GLOBAL INVENTIONS RELATED TO ENVIRONMENTAL MONITORING (2001-2010)

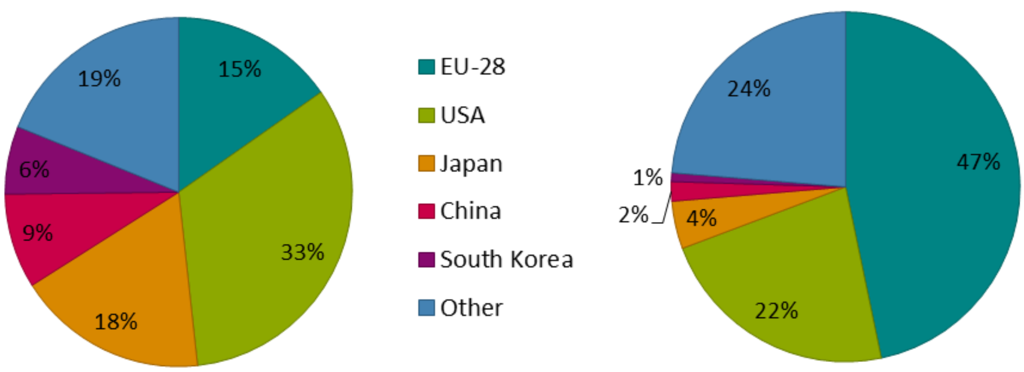


Source: Ecorys et al. (2012)

The two pie charts below show the share of inventions and publications for the main sensor and instrument markets. The left figure shows that the US is the leading country in terms of patents granted. Total patents granted in the period 2001-2011 was 3,765 of which1,241 patents were supplied to US-based companies, equalling 33%. The US is followed by Japan (669 patents) and the EU-28 (jointly 576 patents).

The right figure presents the number of scientific citations in the same period. Between 2001 and 2011 a total of 36,956 scientific citations were made. The EU-28 was leading with 16,796 citations, followed by the US with 8,114. Although the US is leading in the number of patents the EU is leading in the number of publications. Since published papers and scientific citations can be seen as a certain indicator for future inventions, the figures can be seen as a basis for future growth.

FIGURE 5-5 COUNTRY SCORE IN INVENTIONS (LEFT) AND PUBLICATIONS (RIGHT) RELATED TO ENVIRONMENTAL MONITORING BETWEEN 2001-2011



Source: Ecorys et al. (2012), edited by authors

The three main Asian countries (Japan, China and South Korea) have a significant share in the number of patents (jointly 33%), however their share in scientific citations is rather limited (jointly 7%). The main companies applying for a patent are Asian or US-based companies as can be seen in the top-20 patent assignees in the period 2001-2011. Only one EU-based company appears in the list. This is in line with the observation made earlier, that sensor producing companies in the US, but also Asia are larger companies compared to the companies in the EU.

TABLE 5.3 TOP 20 GLOBAL PATENT ASSIGNEES FOR PERIOD 2001-2011

Position	Company name	Country	Number of patents
1	Mitsubishi Group of Companies	Japan	87
2	Boeing Co	USA	84
3	Toyota Jidosha KK	Japan	38
4	Japan Radio Co ltd	Japan	36
5	US sec of Navy	USA	25
6	Lockheed Martin corp.	USA	24
7	Hitachi	Japan	20
8	Thales	France	20
9	Honeywell Inc.	USA	19
10	Schlumberger technology corp.	USA	19
11	NEC corp.	Japan	18
12	Terahop Networks Inc.	USA	18
13	Fujitsu ltd	Japan	16
14	Electronics & Telecom Research Institute.	South Korea	15
15	Furuno Denki KK	Japan	15
16	General Electric co.	USA	15
17	Korean Ocean Res&Dev inst.	South Korea	15
18	Chinese Academy of Sciences	China	14
19	Sony Corp	Japan	14
20	Garmin corp	USA	13

Source: Ecorys et al. (2012), edited by authors

5.3.4 *Synthesis*

Based on the analysis above it is concluded that the European sensor and instrument industry is one of the leading industries globally. However they face difficulties entering the US and Canadian markets and there is competition for the up-coming markets, especially Asia and South America. In terms of patents the US has a far larger share that the EU-28 countries combined. This indicates that currently the US has a larger group of protected environmental monitoring equipment, which provide them with a protected market status and improves their competitive position. European companies cannot offer the same or too similar products, leaving them with a competitive disadvantage. Based on the number publications, which is far higher for EU countries than for the US, it can be concluded that in the EU a good climate exists for R&D which might lead to new sensors and instruments. The role of Asian countries, e.g. China, is still limited in this market and competition from these countries is low.

6. BUSINESS MODELS

Business models, from the viewpoint of WP2, intent to describe how stakeholders participating in a value chain organise themselves to create, deliver and capture added value. This also includes a description of the value chain structure leading to the delivery of the final product, the way stakeholders contributing to that position themselves on the value chain by taking up different activities, as well as the business relations developed between the different stakeholders in their effort to maximise the profit margin they obtain and the development and promotion of product variants. In this chapter we describe the approaches that stakeholders of the environmental monitoring industry have adopted as well as identify the main trends developing regarding the abovementioned issues as a response to the development of the market and compare how far these comply with the principle of business model theory for each phase of the product life-cycle (market maturity – see Ch.3).

6.1 Relation of business models to product life-cycle

Different business model types have been related with the maturity level of markets and the life cycle of products[33]. A comparison is made between the business models applied for the promotion of sensors focused on by NeXOS for environmental monitoring and a relation is drawn with the maturity level of each market segment, the main characteristics of business models for each phase of the product life cycle are presented.

Komninos (2002) defines that the product life-cycle is in close relation and mostly follows the market maturity level for the respective market segments each marine sensor aims at. In short, the product life-cycle starts with the development phase when firms find and start developing a new product idea. Usually, in this period, a product undergoes many changes consuming a large amount of money and time before it is made available to customers usually via targeted test markets or pilot applications aimed to raise clients' awareness of the product's characteristics and added value.

The development phase is followed by the introduction phase where the product aims at acquiring a strong market position and probably faces the first competitors that developed similar products at the same time. In this period, business models emphasise on delivering product variations in order to capture early adopters and meet diversified user requirements. All possible distribution channels are explored in order to penetrate new markets, while the main marketing aim is to further stimulate public awareness of the product. Therefore a lot of resources are usually poured into promoting and advertising the product which should pay back by gaining a stronger market position later on in the product life-cycle.

The growth phase focuses on maintaining and expanding a strong position / market share with competition focused on price and distribution channels. While the early majority of users embrace the product, the business models applied should reinforce the relation with middle-men actors to promote the product distribution and emphasise on product upgrades to maintain market share by discouraging competition. Technology leaders should at this phase be fast in their efforts to develop the market as new technologies usually trigger a quick development of competing products. Product promotion and advertisement at this point is focused at maintaining a market leader profile rather than raising market awareness.

The maturity phase arrives when the market becomes saturated and product variations have already covered most of the clients' diversified requirements. This is the period that yields the most profit to companies that have succeeded in safeguarding a strong market position, capitalising on the product adoption by the late majority. The business models at this point aim to defend the market position by decreasing prices. At this phase, emphasis on maintaining a "loyal" middlemen basis is essential to maintain the market share. A successful product will extend its maturity phase beyond that of competing products by differentiation from the competition in matters of quality and reliability which is

[33] Wirtz (2011)

emphasised also by product promotion strategies.

Finally the declining phase of a product is maybe the most difficult to handle. Since it follows a period of increased sales, optimism for the product future might deter from understanding the actual market status. The withdrawal of a product from the market should be dealt with cautiously and after good assessment. Usually first the least performing markets and product variations are abandoned and distribution channels are limited to the ones that deliver the main bulk of sales. Prices should be carefully set especially when a new product is launched in order to replace the old one. Product users should be carefully stirred to the new product, while taking care of retaining a high combined sales volume and profit for the two products.

Of course the sequence and duration of product phases is not identical for all products and market segments. The duration of each phase is highly dependent on the overall market characteristics and the pace at which competing actors introduce new technologies. Usually, technology pioneers are the ones to set the pace and introduce new technological developments only as a means to defending their market shares as a response to the evolution of competing products.

The following table summarises a recommended approach for evolving a product's business model according to the phase of their product life-cycle.

TABLE 6.1: STRATEGIES FOR EACH PHASE OF PRODUCT LIFE-CYCLE

	Development Phase	Introduction Phase	Growth Phase	Maturity phase	Decline phase
Strategic Goal	Make product known and establish a test period	Acquire a strong market position	Maintain your market position and build on it	Defend market position from competitors and improve product	"Mlik" all remaining profits from product
Competition	Almost not there	Early entry of aggressive competitors into the market	Price and distribution channel pressure	Establishment of competitive environment	Some competitors are already withdrawing from market
Product	Limited number of variations	Introduction of product variations and models	Improvement – upgrade of product	Price decrease	Variations and models that are not profitable are withdrawn
Price Goal	High emphasising to sales though middle men	Aggressive price policy for sales increase	Re-estimation of price policy	Defensive price policy	Maintain price level for small profit
Promotion Goal	Creation of public market product awareness	Reinforcement of product awareness and preference	Reinforcement of middle men	Maintain loyal to middle men	Gradual decrease
Distribution Goal	Exclusive and selective distribution through certain distribution channels and creation of high profit	General and reinforced distribution through all distribution channels available	General and reinforced distribution with good supply to the middle men while limiting their profit margin	General and reinforced distribution with good supply to the middle men	Withdrawal from most channels of distribution

	Development Phase	Introduction Phase	Growth Phase	Maturity phase	Decline phase
	margins for middle men				

Source: Adapted from Komninos (2002)

6.2 Business models observed

Examining the European sector of marine environmental monitoring sensors, a variety of applied business models has been identified. The variety of activities using marine sensors, as well as the diversification of the aim of their use and the geographical scope of the different market segments create a unique market environment for each sensor product. It is therefore justifiable that the firms of the sector have been applying a variety of business models in order to develop their businesses.

The main variations in the business models applied regard the way sensor manufacturing firms position themselves on the value chain and, subsequently, the cooperation they develop with other stakeholder groups. The development phase of the market segment is in many cases critical for the way these business models unfold.

The main business model variations that were identified are formed by the decisions made regarding a small set of parameters. These parameters include:

- The number and type of stakeholders involved in the part of the value chain downstream of the manufacturer. Meaning, whether except of the manufacturer and end-user actors, also service providers and sensor integrators/developers are involved or not.
- The value chain activities each stakeholder performs. In specific whether the manufacturers expand their scope of activities downstream on the value chain to also design and set up the data collection activity, collect and analyse environmental data and provide monitoring services or not.
- The ownership status of the sensors. Which actors operate the sensors and whether they have bought or leased them.

Theoretically, the variants to the business models could be as many as the possible combinations of the different values of above parameters. Practically, not all of the possible combinations are found in the market. Nevertheless, as new market segments evolve and their maturity levels diversify, the business models that will be met will become increasingly diversified as one model can not suit all market conditions.

The main models that have been observed include a common denominator which is the sensor manufacturer taking on the sensor manufacturing activity, but can unfold in a number of ways. The identified business models are highly dependent on the aim of the monitoring activity which leads their diversification. Hereunder they are described in brief:

1. For research-oriented activities, (where the ownership of the sensors usually lays with the end user):

    a. Manufacturers sell off-the self sensors to end users who take on the rest of the value chain. This is a model that is not broadly applied due to the lack of standardisation of sensors, but as standards arise it will possibly be the case for most simple and well established research-oriented monitoring activities;

    b. A variation of the above currently applies for most research applications where manufacturers cooperate with end users in developing the starting from a basic model and are modified in order to fit the requirements of end users, who then take on the rest of the value chain;;

    c. A 3- layer model with an intermediate sensor developer/integrator actor role emerging when the complexity of research activities increases requiring the combination of multiple sensors on a single platform (e.g. climate research where complex observatories call for a specialist middle man to integrate sensor platforms). This is the case especially if the end user possesses limited knowledge on sensor development and integration in which case the integrator takes up the compilation of the observatory for the end user.

2. For industrial and legal requirements (where sensor ownership lays with the end user):
    a. Manufacturers (taking on, if necessary, the development step) provide products to end-users who perform the rest of the activities. This is usually the case with industrial applications with high relevance to process monitoring where end users want to be in full overview of the process (i.e. applications to promote event-driven responses for oil & gas/off-shore wind sectors)
    b. Alternatively, in case more complex systems are needed, a system developer / integrator may procure the system to the end user.
    c. Service providers obtain from manufacturers the necessary equipment (before selling to the end user), while they set up and operate the monitoring activity. This is more the case in industrial- or legal-aimed applications where the end user has limited capacity (or interest) to take over the operation of the monitoring activity.
    d. A 4-layer model evolves from model 2c when the integration of the sensors in platforms is performed by a system developer/integrator instead of a service provider.

3. For industrial and legal requirements (where sensor ownership does not lay with the end user):
    a. Similar to model 2c, the service provider might be the owner of the sensor and lease it to the end-user (in case of more limited in time monitoring) with sensors that can subsequently be applied in other instances.
    b. Similar to model 2d, the service provider might be the owner of the sensor and lease it to the end-user.
    c. Manufacturers go all the way in providing the service for the end user. This is the case when the logistics and time scope of the activities are limited and the manufacturer has the capacity to take them over. In this case the manufacturer is the owner of the equipment which he might reuse and performs essentially a service for which he charges the end user (i.e. security related monitoring for ports)

In the following table, the identified business models are presented[34] together with the activities each stakeholder group performs in each model.

Aim	Abbrev	Manufacturing	Adaptation	Set-up/integration	Operating	Ownership
Research	1a	Man	(End)	End	End	End
Research	1b	Man	Man/End	End	End	End
Research	1c	Man	(Integr)	Integr	End	End
Ind & Law	2a	Man	(Man)	End	End	End
Ind & Law	2b	Man	(Integr)	Integr	End	End
Ind & Law	2c	Man	(Serv)	Serv	Serv	End
Ind & Law	2d	Man	(Integr)	Integr	Serv	End
Ind & Law	3a	Man	(Serv)	Serv	Serv	Serv
Ind & Law	3b	Man	(Integr)	Integr	Serv	Serv
Ind & Law	3c	Man	Man	Man	Man	Man

34 The order in which the business models are presented does not indicate the popularity of the different models

6.3 Factors defining business models

The strategy leading to the application of the different business models identified is based to a large extend, except from individual vision of the management team of each manufacturing firm, on the market conditions of the market segment of each sensor and the approach and availability of other actors downstream in the value chain.

Currently the augmenting use of sensors to meet industrial and legal aims has given rise to the involvement of an increase in the number of actors taking up a more and more specialised role in the value chain in contrast to previous situations in which the number of involved actors was limited to manufacturers and end-users. The exact form of the business models finally encountered is first and foremost dependent on the following most important factors:

- aim of the monitoring activity
- maturity phase and size of the market

Both these factors influence significantly the existence of intermediate layers of stakeholders to perform the value chain activities between sensor manufacturing and delivery of complete environmental monitoring services.

Specifically, **research applications** are more probable to induce an extended involvement of end-users in activities upstream on the value chain. This is due to the limited profit margins that discourage additional actors from entering the value chain, as well as the willingness of the manufacturers to perform additional activities. While on the other hand, more sophisticated monitoring needs increase sensor requirements and the necessity for sensor adaptation and integration on monitoring platforms.

Industrial applications are usually profit oriented and targeting in improving production processes. Should a profit margin be identified, outsourcing tasks previous to the operation of the monitoring scheme (such as the sensor adaptation and integration) is well expected, however the operation of the data collection and analysis activities is something that end-users in these cases prefer to take over in order to retain control over their production processes.

When the aim of the monitoring activity is **legal,** end-users will tend to keep their involvement as limited as possible and will prefer to outsource the monitoring services as far as possible aiming at meeting minimum requirements. Contributing to that aspect is the fact that environmental monitoring capacity is usually absent (since it is not relevant to the core activity of the end-user) and there is little financial incentive to develop it. Therefore, the introduction of additional actor layers or, should that not be possible, the downstream expansion of manufacturers, is very likely in these cases. Moreover the ownership of the sensors is something the end-users are not interested in retaining, while the strive to meet minimum legal requirements leads to a reduced need to adapt or further develop sensors.

The market maturity phase influences the availability of intermediate layers of actors. **Less mature market** segments tend to produce less room for middle layer stakeholders specialisation. Additionally, should a market be rather new, it might be the case that service providers might not have yet developed the necessary capacity to undertake parts of the value chain. This limits the available channels of delivery for manufacturers' products, whom in this case need to develop themselves a link with the end users. Additionally, in the early stages of a market's life-cycle, product development has not been finalised and there is an increased need to develop new product variants calling for additional activities to valorise the final product.

For more **mature and sizeable** markets middle layers are more probable of claiming larger parts of the market. Whilst, the stabilisation of the market and competing product variants leads to a reduced need for sensor adaptation and additional development, the size of the market makes specialisation of intermediate layers of actors, to perform services, worthwhile.

Finally, early in the **development phase** of new products, manufacturers are practically the sole possible operator of the new sensors. They need to seek for test markets, identify and convince end-users of the usefulness of their products and provide services, in a kind of pilot projects, themselves in order to gain references for their products.

Although the previous are the most significant factors that determine business models, there is a number of additional secondary factors that can determine the scope and activities of each stakeholder in the value chain and dictate the business model approach to be followed in specific circumstances. These factors are the:

- **availability of funds** to end users to outsource activities on the value chain. If funds are not available they are more likely to be “obliged” to perform the monitoring activities themselves;
- **complexity of the monitoring requirements**. More complex monitoring requirements (similarly to the research oriented monitoring) call for additional specialist actor involvement in the value chain.
- **duration of the monitoring activity**. Short term monitoring activities discourage end-users from purchasing the equipment and performing the activities of the value chain themselves.
- **experience** of end users with parts of the monitoring value chain activities **and proximity of the marine monitoring activity** to the end users’ core activities. These two elements provide for the capacity and willingness of end-users to take-up activities upstream on the value chain. Both are necessary, however the willingness is a prerequisite to developing capacity.
- **logistics** involved in performing the marine monitoring activities. The operational capacity of manufacturers to perform the data collection activities in the field of the monitoring activity is also defining the potential of manufacturers to move downstream the value chain to meet the end-users requirements for services.

7. CONCLUSIONS

Typically, marine sensors are used for one of the following particular aims:

- Legal aim: monitoring of the marine environment because legislation requires an actor to do so
- Industrial (commercial) aim: an economic operator uses sensors to monitor or steer its processes, as they are considered the most economically advantageous way to do so
- R&D aims: the use of sensors for the sake of science, without a pre-defined application in mind.

A list of 9 user groups (economic sectors) has been identified that use marine sensors for the purposes of their activities. Below table summarises them and their aims – which can be multiple. Also, the role that sensors play in each of these markets varies: in some sectors sensors are commonly applied (these are considered mature market for sensors) whereas in other markets the use of sensors is still in an infant stage. This also gives the basis for estimating the growth potential of sensor use in each of these markets, which has been assessed qualitatively in the two right-side columns in below table.

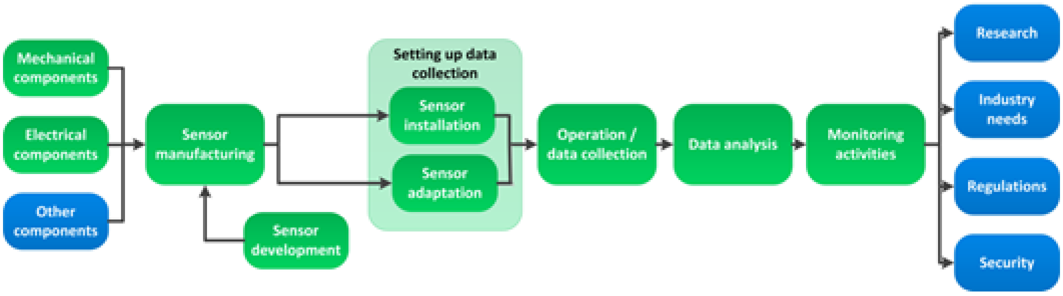
Aim / Market	R&D	Industrial / economic perspective	Legal	Role of sensors	
Sensor aim from the perspective of market sectors				Today	In 2020
Monitoring of environmental quality	√	-	√	○○	○○○
Offshore oil & gas	√	√	√	○○	○○○
Industrial water quality measurements	?	√	√	○○	○○
Oceanographic research	√	√	√	○○	○○
Fisheries	√	√	√	○	○○
Aquaculture	√	√	√	○	○○
Ocean renewable energy	√	√	-	○	○○
Deep sea mining	√	√	-	-	○○○
Port security	√	√	√	○	○○○

Legend: ○ limited role; ○○ average role; ○○○ large role

The size of the global sensor market is not exactly known, but an estimation of the export market of instruments gives figures in the order of € 5.8 billion ($7.5 billion) in 2001, which has risen to € 12.4 billion ($16 billion) in 2011. However this estimation covers a market much wider than the sensor categories assessed within the NeXOS project. Further growth of the use of marine environmental sensors is driven by legal requirements (the Marine Strategy Framework Directive and subsequent monitoring guidance in particular), commercial considerations (sensors being adequate tools to monitor offshore operations and to be cost-effective systems of measurement and control) as well as ongoing research requirements (building on the globally increasing awareness of the importance of the ocean system to mankind).

Leading countries manufacturing sensors are found in the EU and North America, with five countries (USA, UK, Germany, France and Canada) jointly hosting about 62% of the market. However when zooming in on particular sub-segments such as those addressed within NeXOS, such figure may vary widely and individual companies may have an estimated share of more than 50% in a particular field alone.

To assess the competitiveness of the European industry, the value chain for sensors was developed.



Depending on the market to be served, and in particular the maturity level of that market, the role of sensor manufacturers can vary from solely manufacturing the sensor and selling it to providing full services packages including installation, data collection, processing and analysis. Typically, business models evolve from full package services by manufacturers to specialised roles as the markets evolve from development towards growth and mature stages. When generalising across the various submarkets, typically four main stakeholder categories can be identified: sensor manufacturers, sensor developers, monitoring service providers, and users / clients. Each business strategy – and a handful of the possible combinations appear dominant – consists of a combined allocation of tasks across these four (or less of them if roles are combined).

NeXOS aims to provide added value through the development of new innovative sensors. Apart from the particular objectives, a number of general challenges have been identified that are relevant for all three sensor categories. They are summarised below.

Challenge	Optic	Passive acoustic	EAF
Power requirements	√	√	
Stability	√		
Standardisation	√	√	√
Sensor interoperability	√	√	√
Fouling	√		√
Data transportation	√	√	
Gathering real-time data	√	√	

Follow-up actions within WP2 of NeXOS

The results presented in this deliverable (D2.1) provide the stepping stones for subsequent activities, notably the assessment of the added value of NeXOS innovations (task 2.3) and the development of possible business strategies to promote market uptake of these innovations. For task 2.3, the understanding of the key challenges and their importance for main user sectors is an important starting point. For tasks 2.4 and 2.5, the business strategies currently in place in relation to the product development phases identified will give a useful toolbox to develop possible combinations of models that can be pursued.

Obviously before these tasks can be further assessed results from the innovation work packages will be necessary.

Annex A: Bibliography and references

Books and articles

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Annex B: List of abbreviations

ASCS	Subcommittee for the Advancement of Small and Medium Enterprise Competitiveness
BRICS	Brazil Russia India China and South Africa (group of countries)
CFP	Common Fisheries Policy
DCF	Data Collection Framework for Fisheries
DOW	Description of work
DSM	Deep sea mining
EAF	Ecosystem Approach to Fisheries management
EC	European Commission
EU	European Union
GES	Good Environmental Status
GOOS	Global Ocean Observation System
IEEE	Institute of Electrical and Electronics Engineers
IPR	Intellectual property rights
MSFD	Marine Strategy Framework Directive
MS	Member States
MW	Mega Watt
PM	Particulate Matter
R&D	Research and Development
ROW	Rest of World (referring to all non-EU or non-European countries)
STD	Salinity – Temperature – Depth (sensors)
WP	Work Package

Annex C: Interview questionnaire

Main objective and scope of the study:

This interview is part of WP2 of Nexos. The work package analyses the current and future market size and the competitive position of European suppliers within the global industry. Main objectives of WP2 are to assess the economic viability of sensor systems requirements and products as well as to develop industrialisation strategies for the project products where possible.

Nexos focuses on six different innovations of which the first three focus on the development of particular sensors, while the last three are transversal innovations, applicable to all types of sensors:

1. Optical sensor systems;
2. Passive acoustics sensor systems;
3. Ecosystem approach to fisheries management sensor systems (EAF);
4. Sensor anti-fouling;
5. Sensor interface interoperability; and
6. Sensor data interoperability.

All answers provided will be treated with confidentiality and will be used only after aggregation with other input and by no means in a form that reveals the interviewee's identity (or that of the organisation employing him). Further, no information will be published without the prior consent of the interviewee.

Main interview topics:

General information:	
Organization name	
Name interviewee	
Contact details (internal use only)	
Type of company (industry, research organisation, university) and (manufacturer, developer, client)	
Focus on which innovation(s) Optical sensor systems, passive acoustics sensor systems, EAF sensor systems Sensor anti-fouling, sensor interface interoperability, sensor data interoperability	
What is the size of your company? How many employees work within your company? And how many work on sensors?	

- In case sensors are developed, which type of sensor is produced?
- In case platforms are used, please specify which types of platforms that are?
- In case systems are used, please specify the system applications and capabilities

Current market and users:

	Market segments	
1	Could you describe your product mix? Do you sell one type of sensors only or a mix? Please, specify.	
2	For what type of activities are your sensors used for?	
3	What kind of services are currently offered by your company?	
4	Are there other activities in which the same (or similar) type of sensors could be used and in which you (would) consider expanding in the short term?	
5	Are there other types of sensors in the production of which you (would) consider expanding in the short term?	
6	What are the drivers for the above decisions?	

	Market structure	
Please answer the following questions separately for each type of sensor your company produces or is considering to produce		
7	What different models of the sensors you produce?	
8	Can you estimate how many sensors are sold worldwide per year?	
9	Can you estimate how many sensors are sold in Europe per year?	
10	How many sensors do you sell? Can you estimate your market share in your country, the EU and worldwide?	
11	What is the selling price of your sensors? Do you know what is the price range of similar sensors produced by your competitors?	
12	Who are your main suppliers? Could you please indicated your top 5 suppliers? What do they supply to you? Are you satisfied with their services?	
13	Who are your main clients? Please indicate your top 5 clients Where are they based ? Are they from the public or the private sector? What is the main business of your clients?	
14	What are the needs of your clients regarding the use of sensors? What is the level of client satisfaction to your services? Do you get requests for services that fall outside your scope?	
15	Who are your main competitors?	

	Market structure	
	Please indicate your top 5 competitors Where are they based? Are they large companies or SMEs? Indication of number of sensors they sell? What is their competitive advantage?	
16	Does your company receive subsidies? If so, by whom and what are they related to? How important are those subsidies to you? (e.g. % of overall budget)? Other forms of funding?	

	Fabrication / development process	
17	Can you briefly describe the inputs to your production process? (Materials, machines, labour etc.)	
18	What challenges / limitations do you face? Availability of materials? Specialized machines needed? Availability of skilled labour?	
19	What are the main technological challenges you face? Could you give an example?	
20	What are your main R&D activities? What % of your budget is spent on R&D? How does that translate in euros/year? Examples of R&D activities?	
21	What would ideally be you top 3 research projects?	

	Drivers for demand	
22	What are the driving factors for ocean observing? Could you give an example? E.g. regulation, environmental / social awareness	
23	Which actions do you take to develop your market? E.g. advertisement, conferences, technical publications, etc.?	
24	Is legislation and regulation influencing your business? EU or national? Is regulation restricting your market opportunities or broadening it? Could you please give an example?	
25	Are there additional policy driven needs? What would you need to strengthen your business and sell more sensors? Could you give an example? Should policies be adopted at EU or national level?	

	Future trends (2030)	
26	What are the expected trends / future development with regard to the market? Could you give an example? How will this influence your business in matters of: Change in # of products sold? Change in product mix? Tougher competition?	
27	Is there new upcoming regulation? How does it influence your market position?	
28	Do you expect a shift of demand in the coming years? Will this be a shift in products (scope)? Will this be a geographical shift? How will this affect your market size / business?	
29	What are the expected trends from the supply side? Could you give an example?	

	Barriers for further development	
30	What are the main barriers you see in the further development of your organisation?	
31	How do the following aspects influence your work: Access to finance? Access to knowledge Access to qualified labour? Access to (new) markets? IPR issues? International policy (incl. trade restrictions for technology)? Any other factors that tamper development?	

Added value Nexos

- What is the reason for you to participate in NeXOS?
- What types of problems could NeXOS solve for you?
- What do you think is the main benefit of NeXOS for you?

Any other issues that participants would like to discuss with regard to market development and competitiveness.

Additional questions for research organisations and universities

The following questions refer to the connection with the NeXOS – project:

- What are the main goals/objectives of your research activities?
- What are your user's needs?
  - What would you need for future research?
- What are future possibilities in marine research?
  - And what do you need to optimize these possibilities?
- What is needed in terms of regulations?

- What are the societal benefits of marine research?
  - Could you give an example?
- Do you see any business consolidations likely to occur in this area?
- What industries drive the demand for research?
- What would your top 5 research needs be?

Annex D: List of interviewees

The table presents an overview of all consortium partners interviewed by Ecorys as input for the market analysis and the competitiveness assessment.

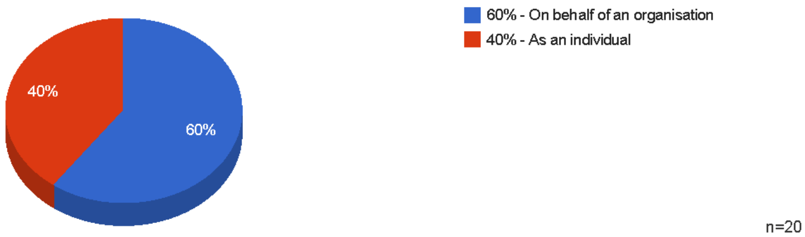
Organisation	Name	Date
1st round interviews		
Ifremer (Institut Francaisde Recherche pour L'Explotation de la Mer)	Jean-François Rolin	4 March 2014
Franatech	Michel Masson	4 March 2014
University of Bremen	Christoph Waldmann	5 March 2014
Trios Mess- und datentechnik	Rüdiger Heuermann	7 March 2014
SMID Technology s.r.l.	Luigi Corradino	13 March 2014
ACSA-ALCEN (Architecture et conception de systemes Avances)	Patrice Pla	20 March 2014
Uni Research	Svein Osterhus	26 March 2014
NKE instrumentation	Patrice Brault Yves Dégrés	3 April 2014
2nd round interviews		
University of Oldenburg	Oliver Zielinski	27 May 2014
Runde Miljøcentrum	Nils Roar	4 June 2014
SMID Technology s.r.l.	Luigi Corradino	5 June 2014
Plocan	Eric Delory	10 June 2014
CMR (Christian Michelsen Research)	David Peddie	11 June 2014
Statoil	Christian Collin-Hansen	16 June 2014
Biotope	Erwan Roussel	26 June 2014
Invivo	Herve Bizien Guillaume Jaqc	8 July 2014

Annex E: Online questionnaire

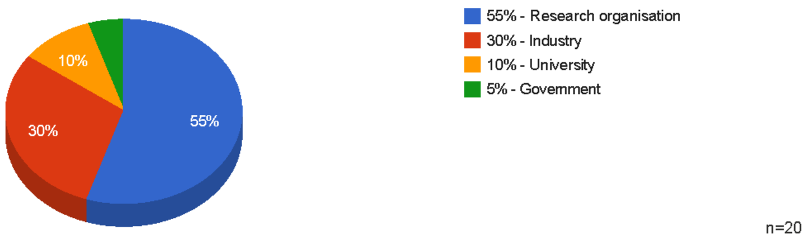
Marine sensor assessment

Status:	Live	Partial completes:	3 (15%)
Start date:	11-06-2014	Screened out:	0 (0%)
End date:	31-08-2014	Reached end:	17 (85%)
Live:	79 days	Total responded:	20
Questions:	12		

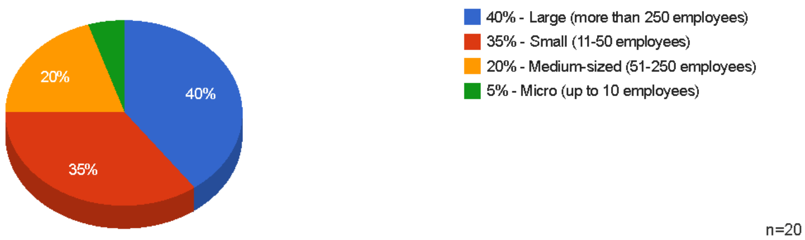
1. Are you answering this questionnaire on behalf of an organisation or as an individual?



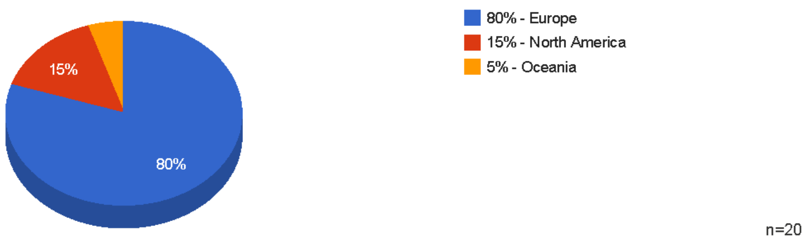
2. What type of organisation is it? If you are replying as an individual, but based on your affiliation to an organisation, please indicate the nature of that organisation.



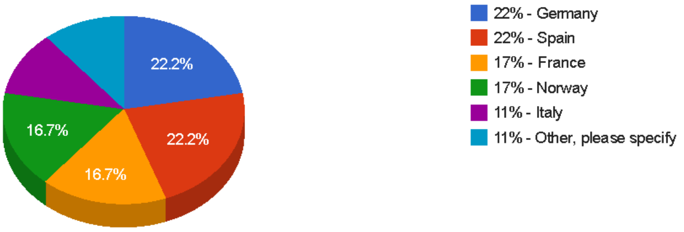
3. What is the size of your organisation?



4. Where are you based?



5. If based in Europe, please select where



n=18

6. What is your relationship to maritime sensors?

(Each respondent could choose **MULTIPLE** responses.)

Response	Total	% of responses	%
1 Manufacturer	2		10%
2 Developer	9		45%
3 Platform integrator	8		40%
4 Service provider*	9		45%
5 End-user**	7		35%
6 Other, please specify	2		10%
Total respondents: 20 **Skipped question: 0**		0% 20% 40% 60% 80%	

Explanation*As service providers we classify organisations that perform activities for third parties like: setting up sensors, sensor operation, data collection and/or analysis of monitoring results) As end-users we classify organisations that are users of the results of the monitoring activities performed with sensors, either they operate sensor them selves or via third parties.**

7. Which industries are you active in?

(Each respondent could choose **MULTIPLE** responses.)

Response	Total	% of responses	%
1 Sensor production	5		25%
2 Oil and gas	5		25%
3 Environmental monitoring	19		95%
4 Deep sea mining	2		10%
5 Climate monitoring	9		45%
6 Fisheries	5		25%
7 Sea life monitoring	6		30%
8 Port sector	3		15%
9 Defence	3		15%
10 Seismic research	1		5%
11 Aquaculture	3		15%
12 Water treatment	1		5%
13 Other, please specify	4		20%
Total respondents: 20 **Skipped question: 0**		0% 20% 40% 60% 80%	

Page 2 of 5

8. What types of sensor are you related to?

(Each respondent could choose **MULTIPLE** responses.)

Response	Total	%
1 Optical sensors	16	80%
2 Passive acoustic sensors	13	65%
3 Ecosystem approach to fisheries management sensor systems (EAF)	4	20%
4 Electric sensors	5	25%
5 Other, please specify	6	30%

Total respondents: 20
Skipped question: 0

9. How important are the following sensor qualifications for you when choosing a specific sensor?

(Each respondent could choose only **ONE** response per sub-question.)

Sub-questions	Resp.	% of responses
Sensor operational attributes	16	19 / 44 / 31 / 6
Sensor interface interoperability	17	29 / 47 / 18 / 6
Sensor data interoperability	17	6 / 35 / 35 / 18 / 6
Power requirements	17	12 / 12 / 6 / 41 / 24 / 6
Anti-foulling	17	6 / 12 / 24 / 24 / 29 / 6
Sensor size	17	6 / 47 / 24 / 18 / 6
Purchasing costs	17	29 / 53 / 12 / 6
Maintenance costs	17	6 / 24 / 65 / 6
Reliability	17	6 / 53 / 41
Robustness	17	12 / 47 / 41
Experience with the same sensor	17	12 / 24 / 59 / 6
Experience with the same manufacturer	17	29 / 29 / 24 / 18
Sensor references	17	12 / 53 / 29 / 6
Sensor reputation	17	6 / 41 / 35 / 12 / 6
Other, please specify	4	50 / 25 / 25

Average: 3,73 — Median: 4

1. Not important
2. Low importance
3. Average importance
4. High importance
5. Extreme importance

- N/A

10. How do you see the use of sensors evolving in the following activities until 2025?
(Each respondent could choose only **ONE** response per sub-question.)

Sub-questions	Resp.	% of responses
Oil and Gas	17	6, 24, 53, 18
Environmental monitoring	17	12, 35, 47, 6
Mammal research	17	12, 29, 18, 18, 24
Fisheries	17	6, 12, 59, 18, 6
Deep sea mining	17	12, 29, 24, 35
Climate research	15	13, 47, 40
Artic research	17	12, 35, 47, 6
Port security	17	6, 18, 29, 18, 29
Ballast water quality control	17	6, 24, 41, 24, 6
Aquaculture	17	12, 24, 35, 12, 18
Water quality control	17	6, 24, 35, 29, 6
Seismic research	17	6, 35, 12, 6, 41
Defence	17	12, 6, 24, 18, 41
Other, please specify	4	25, 75

Average: 4 — Median: 4

- 1. Rapidly declining
- 2. Slowly declining
- 3. Stable
- 4. Slowly expanding
- 5. Greatly expanding
- \- N/A

Page 4 of 5

11. According to your opinion, what are the main barriers hampering the development of the marine sensor industry in Europe?

(Each respondent could choose **MULTIPLE** responses.)

Response	Total	%
1 Lack of skilled employees	5	29%
2 Lack of funds to invest	12	71%
3 Cost of data monitoring	4	24%
4 Cost of data transfer	1	6%
5 Cost of sensor operation	6	35%
6 Cost of maintenance	5	29%
7 Lack of sensor references	2	12%
8 Lack of internal competition	2	12%
9 Lack of quality antifouling solutions	1	6%
10 Limited access to local markets	3	18%
11 Strong external competition	3	18%
12 Other, please specify	4	24%
13 None of the above	0	0%

Total respondents: 17
Skipped question: 0

12. What could the EU do to stimulate the maritime sensor market?

(Each respondent could choose **MULTIPLE** responses.)

Response	Total	%
1 Stimulate small and medium-sized enterprises	11	65%
2 Introduce a funding scheme	7	41%
3 Stimulate European wide research programs	8	47%
4 Introduce piloting projects	7	41%
5 Promote standardisation protocols	8	47%
6 Adopt new regulations	3	18%
7 Other, please specify	2	12%
8 None of the above	0	0%

Total respondents: 17
Skipped question: 0