D.2.3– Economic Feasibility of NeXOS Innovations

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Abstract

This deliverable is named “Economic feasibility of NeXOS Innovations” and addresses, as per the Description of Work, the added value of the NeXOS innovations in comparison to existing technologies. This Deliverable builds upon the findings of tasks 2.1 (market analysis) and 2.2 (competitiveness) on which Deliverable D2.1 has reported.

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:

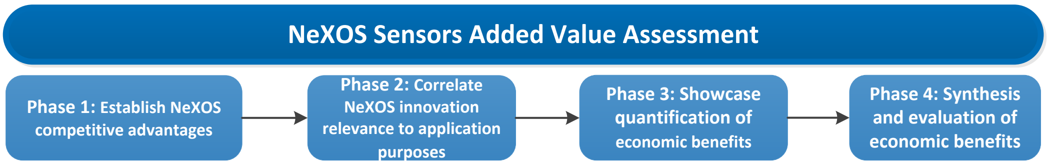
- Assess the economic viability of sensor system requirements and products; and
- Develop industrialisation strategies for the projects, where applicable.

Task 2.3: Added value of NeXOS innovations seeks to assess the economic advantages of the innovations developed, by:

- Identifying the main advantages (cost savings in hardware and improvements in operational efficiency, quality etc.), and assumptions (operational lifetime, costs, maintenance needs and replacement rates), as well as
- Quantifying, where possible, said advantages and assumptions in order to arrive at a concrete conclusion regarding the expected market uptake of the NeXOS products.

This report investigates, identifies and (to the extent possible) quantifies the added value that the NeXOS innovations are expected to bring to the industry, and assesses the uptake in the respective markets that were identified in D2.1.

In order to achieve this, a tailored methodology is developed that breaks down the process of assessing the added value of innovations in four phases.



In total, nine parameters are identified as critical differences between various instruments and used to pinpoint the value proposition of the NeXOS innovations. These parameters are:

1. Physical properties – Dimensions and Weight;
2. Power consumption;
3. Multifunctionality (No. measured parameters);
4. Capital and operational costs (CAPEX and OPEX);
5. Operational Depth (and temperature);
6. Quality of measurements (Range and Accuracy);
7. Maintenance requirements (Antifouling technology);
8. Interface interoperability (Plug-and-Play);
9. Data interoperability and communication load.

Within task 2.3, we have attempted to quantify, where possible, the added value and, consequently, attach the respective benefits to each NeXOS innovation. This assessment has been an arduous process which has encountered the following barriers:

- NeXOS product development was still ongoing at the time of the original submission date of this deliverable, so that significant data was not yet available. Also the process of operationalising the NeXOS products was not (and still is not) yet fully complete, rendering the estimation of (especially) operational costs additionally difficult.

- NeXOS products are unique, for most of them there are no comparable instruments in the market performing the same functionalities. As such, comparison can only be performed on a theoretical level and regarding specific aspects. This will necessarily leave out of scope of the comparison some of the main NEXOS innovations capacities, such as the possibility to measure new parameters. To showcase the advancements, combinations of products have been taken into account, under the assumption that these are possible and the competing products can co-exist simultaneously.
- Availability of information especially regarding competition is scarce. It has been very hard to obtain CAPEX and OPEX figures from non-NeXOS manufacturers as they are not willing to disclose these information to non-customers. Where possible estimations from users have been applied; however this is also constrained by the limits in the thinking of the users in matters of complete operational (life-cycle) costs.
- Components of OPEX are, for a large part, usage related and mission specific. These figures can only be estimated given the fact that the products are not yet fully developed and used in real situations. Critical estimations had to be made (e.g. regarding frequency of maintenance, workload for data processing etc.) based on expert judgements of users, rather than based on measurements of actual processes. In this respect, we have devised a number of use cases to theoretically and consistently assess the operational costs under various monitoring set-ups of sensor/platform combinations.
- As indicated in deliverable D2.1, in relation to market size and economic assessments, very limited to no relevant information has been found. Additional effort was put in reviewing the public documentation of other Horizon2020, FP7 / Oceans of Tomorrow research projects. It appeared that those projects did not contain dedicated market analysis or added value assessments, and the effort undertaken under NeXOS WP2 is unique in its level of detail. Despite efforts to reach out to other research teams for exchange of non-public information, this has not been met with fruition. Eventually the quantification of costs and estimations of market developments has been based on whatever data has been found available, including incremental and older information.

Still, the analysis showed that all the NeXOS innovations have positive effects for their potential users as well as for the markets altogether. The most significant sources of quantifiable added value appear to be in the areas of reduced power consumption and lower maintenance needs. These two characteristics of the NeXOS innovations are found to bring significant benefits, strengthening the value proposition of the total project remarkably. Quantitative benefits are presented in the respective sections under Chapter 7. Extensive use has been made of the cost analysis and use cases developed under WP3 (refer to Deliverable 3.6). A summary in qualitative terms is given in the table below, where the scores relate to small added value (+), medium added value (++) or large added value (+++).

TABLE 1: ASSESSMENT OF BENEFITS AND COST SAVINGS OF THE NEXOS INNOVATIONS

NeXOS improvements	A1	A2	O1	O2	O3	EAF
Physical properties	+	+	+++	+++	++	+++
Power consumption	++	+	+++	+++	+	++
Multifunctionality	++	++	+++	+++	+	+++
Capital & operational costs	+++	++	+++	++	+	+++
Operational depth	+	+	+	++	+	+
Quality of measurements	++	++	+	+++	++	++
Maintenance (antifouling)	-	-	+++	+++	+++	++

Interface interoperability	++	+	++	+++	+++	+++
Data interoperability	+++	+++	++	++	++	++
-: not applicable						

Subsequently, the identified benefits per innovation are coupled with the findings of deliverable D2.1 on market assessment and competitiveness. As each market has specific needs, it is expected that said benefits impact each market differently. Three routes to market uptake are identified, namely:

1. Expanding their share in existing markets (e.g. by outperforming competition);
2. Creating the potential to increase market size as a result of improved NeXOS characteristics (e.g. by facilitating measurements or due to the introduction of new product and services);
3. Enabling the use of the NeXOS sensors in new market segments.

As such, the quantitative analysis of the expected market uptake has shown positive impacts for the vast majority of the cases, as shown in the following table.

TABLE 2: EXPECTED MARKET UPTAKE OF THE NEXOS INNOVATIONS

NeXOS innovation	Existing markets	Increase markets	New markets
A1 – Acoustic	Offshore oil & gas Offshore renewable energy Deep sea mining Ocean renewable energy ↑	Oceanographic Research ↗	—
A2 – Acoustic	Offshore oil & gas Offshore re. energy Deep sea mining Ocean renewable energy ↑	Oceanographic Research ↑↑	Port security Military operations Data sales ↗
O1 - Optical	Offshore oil & gas Deep sea mining ↑	Monitoring of environmental quality Oceanographic Research Industrial water quality measurements ↑↑	Aquaculture Data sales ↑↑
O2 - Optical	Offshore oil & gas Deep sea mining ↑	Monitoring of environmental quality Oceanographic Research Industrial water quality measurements ↑↑	Aquaculture Data sales ↑↑
O3 - Optical	Offshore oil & gas Deep sea mining ↑	Monitoring of environmental quality Oceanographic Research Industrial water quality ↑↑	Aquaculture Data sales ↗

NeXOS innovation	Existing markets	Increase markets	New markets
		measurements	
EAF - Combination		Monitoring of environmental quality Aquaculture	Data sales
Transversal - Antifouling	Offshore oil & gas Offshore ren. energy Deep sea mining Ocean renewable energy	Monitoring of environmental quality Oceanographic Research Industrial water quality measurements	Third-party sensor development
Transversal – Interface interoperability	All markets		
Transversal – Data interoperability	Offshore oil & gas Deep sea mining	Oceanographic Research Monitoring of environmental quality Aquaculture Industrial water quality measurements	Data sales

Finally, this report also covers the progress of the innovation development process. Through close monitoring of the process by the Subcommittee for the Advancement of Small and Medium Enterprise Competitiveness (ASCS), a subcommittee set up within the NeXOS consortium, the added value of the end products is maximised. This process, using a set of success indicators to track the progress in the development of the innovations, has proved highly successful in communicating the right set of requirements amongst the partners, ensuring the creation of successful products.

The results of this added value assessment is used as input for tasks 2.4 in which business models for industrialisation are evaluated, and 2.5, where industrialisation strategies are developed.

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1. INTRODUCTION

1.1 Background and objectives of WP2

1.1.1 *The NeXOS project*

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 ecosystems and their balances can be easily disturbed. 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 altered or disturbed, other processes may also be affected and cause impacts on its surroundings.

As 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, Flora and Fauna[3] and Birds[4]. The Water Framework Directive (WFD) and the Marine Strategy Framework Directive (MSFD) have also been adopted in order to protect the seas and oceans of Europe[5].

These directives ask for monitoring the seas and oceans around us. They do not specify how these 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 as well as the physical constraints of platforms, that sometimes prevent integration on the desired platform, 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 addressed by NeXOS include ocean optics, ocean passive acoustics and the Ecosystem Approach to Fisheries management (EAF) sensor systems. In addition, downstream services for the Global Ocean Observation System (GOOS), the Good Environmental Status (GES) and the Common Fisheries Policy (CFP) will be developed. In order 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;

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

7. To assess and optimise the economic feasibility and viability of the new sensor developments including the manufacturing phase;
8. To demonstrate these new sensor and system 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. One of these supporting Work Packages, WP 2, focuses on the economic viability and industrialisation of the NeXOS innovations.

1.1.2 *Work package 2 - Economic viability and industrialisation strategy*

Work Package 2 (WP2) 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, 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 as well as 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, namely:

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).

In Task 2.1, the overall size of the market for environmental monitoring, the types of services currently offered as well as the types of equipment involved have been assessed. Also, the nature of the clients and the relevance of monitoring data have been investigated. Based on the outcomes an indication of the current market size is available, next to the expected trends in volume and budgets as well as a shift in demand for specific markets. This task has been completed. Results can be found in Deliverable 2.1.

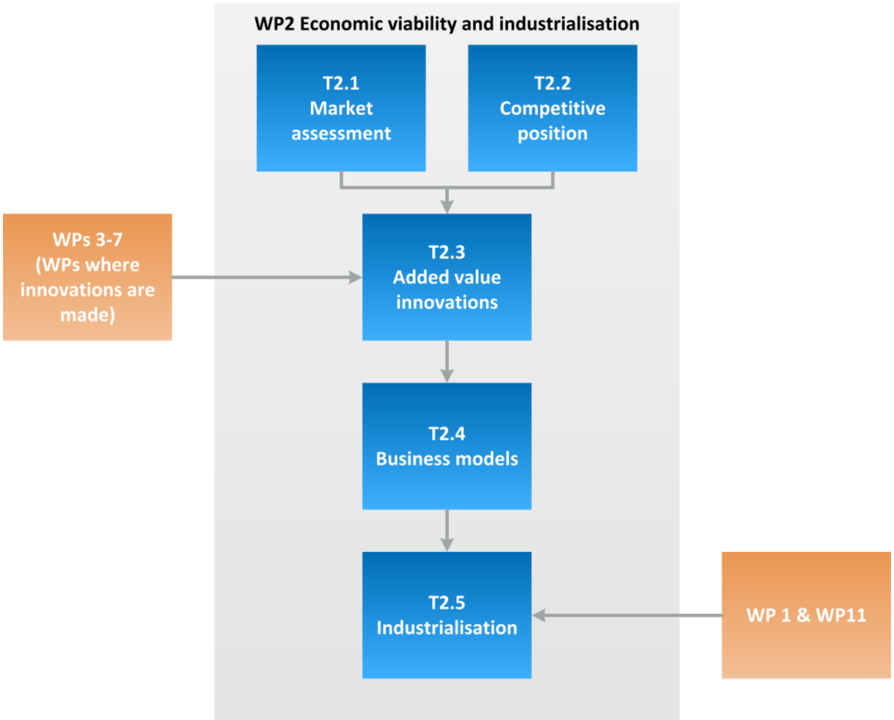
In Task 2.2, the competitive position of the European suppliers in the global industry has been assessed. This step is of vital importance, since the feasibility and the success of the innovations developed under NeXOS depend on this position. Other factors influencing the feasibility are the quality 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. This task has been completed as well and results can be found in Deliverable 2.1.

In Task 2.3, the economic added value, that the NeXOS innovations bring, is determined. At this stage, an analysis framework is developed that identifies the main advantages and assumptions and, consequently, attempts the quantification thereof. Using the outcomes of tasks 2.1 and 2.2, this task further builds upon inputs from WPs 3-7, where the actual innovations will be developed. The results of the added value analysis are the topic of this deliverable (D2.3).

The outcomes of the tasks 2.1 – 2.3 feed into task 2.4 in which possible business models for the introduction of the new innovations will be designed. Task 2.5 needs inputs from WPs 1 and 11 and will further elaborate on industrialisation strategies to commercialise the innovations done under

NeXOS. Results of those tasks will be reported upon in Deliverable D2.4. The figure below shows the interdependencies between WP2 and the other WPs.

Figure 1.1: Relation between WP2 and other NeXOS tasks



Source: Ecorys (2014).

1.2 Aim and set-up of this deliverable

In purely accounting terms, economic value added is considered as the incremental difference in the rate of return over a firm's cost of capital. It is a measure of economic profit in the form of surplus value created on an investment[6]. For the purposes of this project, it is necessary to approach the added value concept from a wider perspective, that of the environmental monitoring market and not the individual firm. In that sense, the added value here is defined as the economic advantages that the NeXOS innovations, as they are presented in this document, can bring to the market. Therefore, it can be described as the measure of how much the economy benefits from the introduction of the NeXOS innovations.

This report covers task 2.3 'Added value of NeXOS innovations'. It is closely related to the previous tasks 2.1 (market assessment) and 2.2 (competitiveness), as inputs from these will be used to facilitate the result. Task 2.3 aims to assess the added value of the innovations developed within NeXOS by:

- developing a framework of analysis which identifies the main advantages (cost savings in hardware and improvements in operational efficiency etc.) and assumptions;
- quantifying these advantages and assumptions where possible, using the technical information derived from the other WPs as well as other inputs such as literature, interviews and user group opinions;
- evaluating the market uptake potential of the new sensors and transversal innovations, using all aforementioned inputs.

The report follows closely the methodology developed and described in the coming chapters and is essentially comprised of three parts namely identify advantages, recognise the benefits that they bring

[6] Please refer to: Prof. A. Damodaran, NYU Stern school of business, http://pages.stern.nyu.edu/~adamodar/New_Home_Page/lectures/eva.html and Stern Value Management, Proprietary Tools, http://sternvaluemanagement.com/intellectual-property-joel-stern/proprietary-tools-value-creation/.

and, finally, and to the extent possible, quantify these benefits.

1.3 Deliverable structure

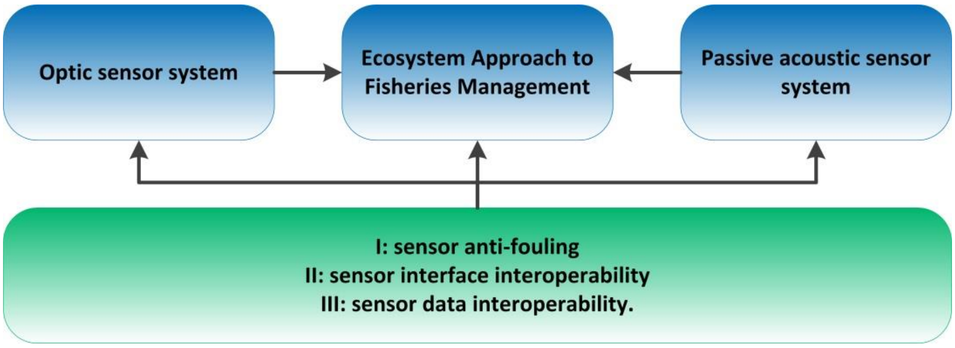
This report kicks off with an overview of the scope of this study, presenting briefly the innovations developed within NeXOS (Ch.2). Following that is chapter 3, where the methodological approach is presented and analysed step by step. As the ASCS is an important source of input for some of the phases of the methodology, chapter 4 contains an extensive overview of the ASCS related activities as well as the outcomes and improvements generated as a result. The remaining part of the report follows the methodology structure. In chapter 5, the NeXOS innovations are compared against available competitor solutions, one by one. For this part, the transversal innovations have been regarded as part of the optical and acoustic NeXOS products. Chapter 6 has three main elements. First the advantages identified in the comparison are linked to operational benefits and added value sources, then these sources of added value are quantified as such and, finally, the specific added value per NeXOS innovation is quantified. Chapter 7 addresses the potential for market uptake that the NeXOS innovations have and is followed by the 8th and final chapter, in which a synthesis of the aforementioned findings is given, along with the conclusions of this study.

2. SCOPE

2.1 The innovations that NeXOS addresses

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).

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.

Challenges to overcome, which are addressed within NeXOS, include reducing the size of sensors, lowering power requirements and improving the measurement capabilities, with the ultimate aim to integrate the optical sensors on a variety of platforms, without extensive (manual) adaptation. The focus of this NeXOS innovation is[7]:

> **** Multi-wavelength fluorescence matrix sensing through different excitation emission pairs combined with reconfigurable chemo metric algorithms providing quasi-EEMS (excitation emission-matrix spectroscopy). The technology brings flexibility, reliability and compactness to different applications, including marine contaminants.***
> **** Hyperspectral cavity absorption sensing following the PSICAM principle: applicability in long-term field application and new algorithms for phytoplankton discrimination as well as dissolved substances.***
> **** Carbon cycle and acidification sensing of pH, pCO2 and alkalinity in a miniaturized and ruggedized setup improved for underwater applications.***

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 the sea and thus have less impact on undersea life forms and environment. With the introduction of the Marine Strategy Framework Directive (MSFD), the demand for passive acoustic sensors has increased and especially cost-effective solutions are sought. Up till now the use of marine acoustic

[7] Descriptions are based on the DoW- table 5 (NeXOS innovations and new technologies).

sensors to gather acoustic data proved to be rather costly.

In the NeXOS project the R&D efforts have mainly focused on reducing the size of the passive acoustic sensor systems, lowering their power requirements and enhancing the pre-processing (and thus the compression) of data to be transmitted. The resulting cost-reduction of data transmission to on-shore facilities is particularly important, as currently open-ocean oceanographic data are sent via high-cost satellite links. More specifically, the NeXOS innovation focuses on:

High resolution, high sampling rate Analog to Digital conversion through 24 bit ΣΔ IC, which grants

- ***a. Wide bandwidth***
- ***b. high dynamic range***
- ***c. Very low input noise level***

The adopted technology (24 bit ΣΔ A/D conversion) will increase dynamic and spectral performance, and multi-functionality.

Specific firmware code will be embedded on the sensor interface for signal pre-processing and source localisation

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 fishing efforts involved, in order to improve operation efficiency. The system can also be used to assess the quality of the fish stock, e.g. the abundance of fish.

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 easily operable and robust, therefore 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 have focused on creating very low-cost systems which have a high autonomy (no interference of fishermen needed) and sensors that are able to better measure chlorophyll and oxygen.

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.

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. The focus of the NeXOS innovation is on:

Biofouling sensor using an innovative optical design.

Use of functionalized surfaces on immersed optical components for fouling protection.

New concept of biofouling control: antifouling protection loop with sensor control.

Transversal innovation 2: sensor interface interoperability

For many application purposes, the monitoring of more than one environmental parameter is required (e.g. temperature, salinity, CO2 concentration); therefore multiple sensors can be installed onto an operating platform, e.g. buoys, gliders or ships. Most sensors are produced by small or medium-sized companies, and a large variety of available sensors, each with their own capabilities, communication protocols, and data format, is founds. 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).

Research efforts of NeXOS have focused on improving the sensor interface operability, preferably by developing a plug-and-play system. The system would enable to use all sensor types on different types of platforms without extensive adaptation and software development. The result would be a cost reduction in system integration. Technical requirements for this innovation are:

***** ***Hardware and software interface based on new CORTEX architectures for a miniaturised low power and modular design with variable frequency clocks ensuring low power consumption or high performance when needed.***
***** ***Implementation of PUCK protocol for instrument discovery and identification in point to point or networks communications.***
***** ***Implementation of PTP (Precision Time Protocol IEEE Std. 1588) for time synchronization.***
***** ***Open Source software development tools facilitate reprograming or reconfiguring sensor interface functionality.***

Transversal innovation 3: sensor data interoperability

Although a 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 readable format 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 GEO. Actions in the right direction already have been taken, but need to be further developed. Focus of NeXOS will be on:

***** ***Implementation of OGC IT standard tools on European ocean sensors, for real-time sensor discovery and monitoring.***
***** ***Implementations of SWE 2.0 to facilitate the interaction and data exchange to and from global observation programmes.***
***** ***Implementation of Sensor Interface Descriptor model for new and existing ocean sensors.***

2.2 Context: markets for monitoring

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 a market assessment was made under task 2.1, of which the results are presented in Deliverable 2.1. a summary is presented here.

In short, the starting point of the market assessment was the analysis of the different market sectors which use marine sensors. For the main market sectors a short description was given, including an overview of the main challenges and barriers, the growth potential and geographical scope.

The market segments (sectors) distinguished in the market assessment, 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.

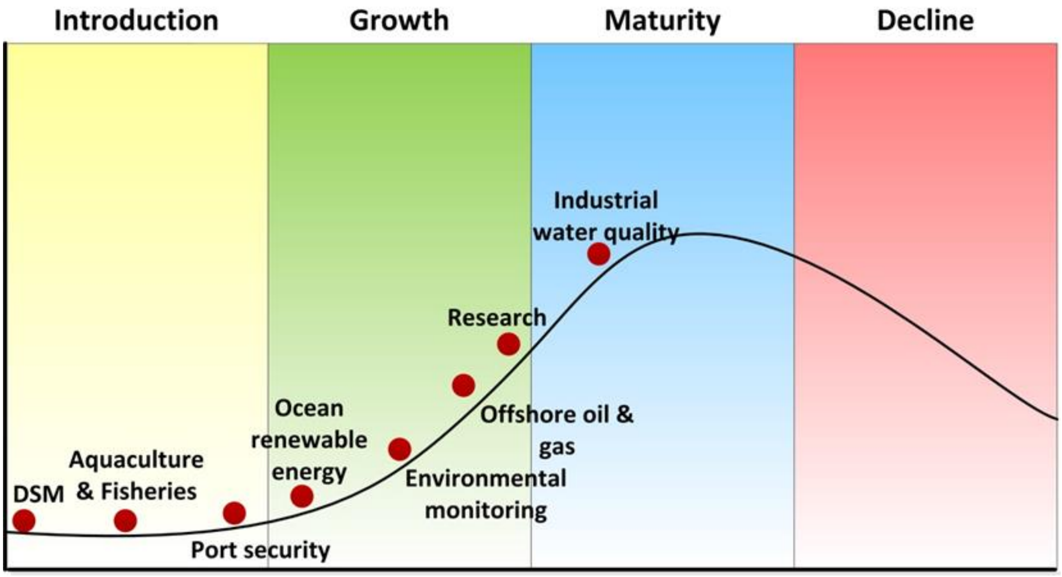
Based on the market descriptions, it is possible to place the different sectors in the different stages of their market development. In order to do so, the product life cycle is used[8]. In figure 2.2 the different sectors are plotted in the product life cycle graph. It should be noted that only the level of sensor use

[8] 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. The four phases are the introduction, the growth phase, maturity and decline.

per sector is considered, irrespective of the development stage of the sector itself. For example, the sector of fisheries obviously is a long established sector, however with regard to sensor use, it is considered to still be 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, and the sector of industrial water quality management is considered most advanced in this regard.

FIGURE 2.2: THE MARKET PHASE FOR EACH SECTOR IN TERMS OF SENSOR USE



Source: Ecorys (2014).

To assess the potential role of sensors in the different markets, two indicators have been defined. First, it is important to know what the current size of the specific sector itself is today and second, what it will be in the coming years. Based on these figures it is possible to estimate whether the sector itself is growing, stabilizing or declining. It is assumed that the uptake of sensor use is larger in growing markets than in markets that are in decline. Both current size of most markets and their size in 2020 have been estimated in the Blue Growth study carried out for DG MARE[9].

Secondly, the current use of sensors needs to be estimated. No complete figures are available for this, but as part of the analysis of task 2.1, the intensity of sensor use was assessed. In some of the sectors, sensor use is non-existent, while in others sensors are already commonly used. In the latter sectors it is expected that the role of sensors will not increase tremendously. The role of sensors is assessed qualitatively and a distinction was made between a limited, an average or a large role.

The table below shows an assessment of the size of the sectors distinguished. Both the current size and the forecasted size in 2020 are presented. The role of sensor use in the different sectors is also assessed, again both current and 2020 level.

TABLE 2-1 EXPECTED SIZE OF THE SECTOR IN THE EU AND THE ROLE OF SENSORS (IN 2020)

	Size of the sector in the EU[10]		Role of sensors in the sector	
	2010 (value added € bn)	2020	2010	2020
Monitoring of environmental quality[11]	4	10	○○	○○○

[9] Ecorys (2012).
[10] Ecorys (2012).
[11] 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.

	Size of the sector in the EU[10]		Role of sensors in the sector	
	2010 (value added € bn)	2020	2010	2020
Offshore oil & gas	120	95	○○	○○○
Industrial water quality measurements	?	?	○○	○○
Oceanographic research	4	10	○○	○○
Fisheries	9	7.5	○	○○
Aquaculture	0.5	0.7	○	○○
Ocean renewable energy[12]	2.4	16.9	○	○○
Deep sea mining	< 0.25	0.3	-	○○○
Port security[13]	3,8	9,7	○	○○○

Legend:

○ limited role

○○ average role

○○○ large role

Based on this market context, as presented in deliverable D2.1 and summarised above, the methodology for assessment of the added value of NeXOS innovations has been developed. This is presented in the next chapter.

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

[13] 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'.

3. METHODOLOGY

Chapter 3 includes a thorough description of the methodology used towards assessing the added value of the NeXOS innovations. The goal is to develop a comprehensive roadmap that can effectively translate technological advancements into tangible benefits that directly reflect to the end users' applications.

3.1 Methodology for added value assessment

As described earlier, this report covers task 2.3 'Added value of NeXOS innovations'. It is closely related to task 2.1 (market assessment) and task 2.2 (competitive position) which elaborated on the competitiveness of the EU sensor manufacturing SMEs vis-à-vis competition. The findings from Deliverable (D2.1), covering these two tasks, provide inputs to facilitate the current analysis. Task 2.3 has three goals;

i) develop an analysis framework to identify main added-value items of the NeXOS innovations;

ii) quantify these advantages to the extent possible; and

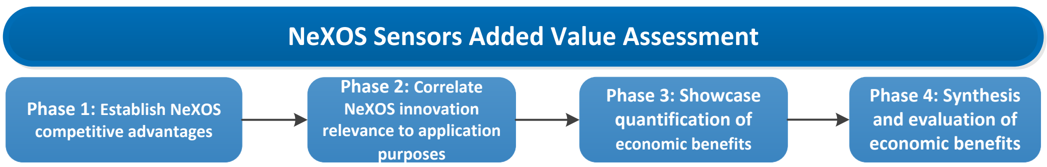
iii) evaluate the market uptake potential of the NeXOS innovations.

All these goals are achieved and relevant questions are answered in this deliverable. This report follows closely the methodology developed and described in the coming paragraphs and is essentially comprised of four parts namely identification of advantages, recognition of the benefits that they bring and, finally, quantification of said benefits and assessment of market uptake potential.

In this paragraph, the methodology developed for the assessment of the NeXOS innovations' economic added value is described. The methodological framework is partitioned in four phases, namely:

- Phase 1: Establish NeXOS competitive advantages
- Phase 2: Correlate NeXOS innovation relevance to application purposes
- Phase 3: Showcase quantification of economic benefits
- Phase 4: Synthesis and evaluation of economic benefits

FIGURE 3.1 THE FOUR PHASES COMPOSING THE ADDED VALUE ASSESSMENT METHODOLOGY



These four phases will be described in detail as follows.

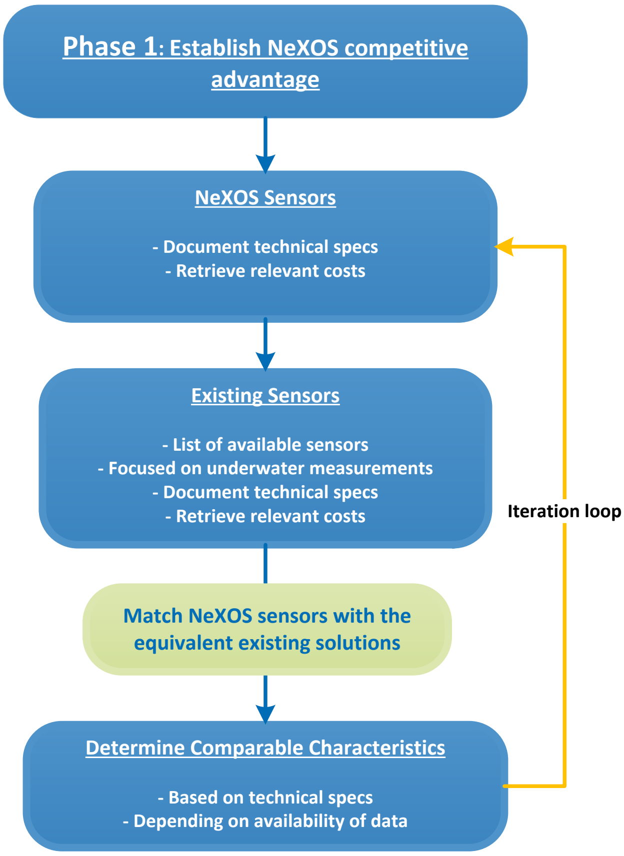
3.1.1 *Phase 1: Establish the NeXOS advantages over the competition*

Phase 1 has the objective of establishing a comprehensive basis to assess the added value of the NeXOS innovations, in which the NeXOS sensors can be examined in contrast to what is already offered by the marine sensor manufacturing industry today. This phase starts by documenting in detail the technical and economic characteristics of the marine sensors, both those developed within NeXOS and similar sensors provided by suppliers off-the-shelf.. Subsequently, a comparison basis is created, matching specifically each of the NeXOS innovations to the currently available solutions, to the extent possible. Therefore, phase one consists of the following 3 steps:

- Step 1.1: Analysis of NeXOS sensors. Using information regarding the technical and economic characteristics of the NeXOS sensors (A1, A2, O1, O2, O3, EAF) using inputs from the relevant development WPs as well as from the members of the ASCS, the fundamental characteristics of the NeXOS innovations and their functions will be identified. The use cases defined in Deliverable 3.6 have been used as the source for operational costs of the NeXOS innovations, based on examples from real-life operations. Transversal innovations are considered as part of the improved NeXOS sensors. This step provides the necessary information in order to be able to understand and identify to which other available sensors they can be compared;

- Step 1.2: Analysis of competing, already existing sensors. Under this step, research has been undertaken in order to list the sensors that are now available in the market, with a particular scope on underwater measurements, relevant to the context of NeXOS. This has been dnoe through exhaustive interviews with project partners, who are also users of similar instruments, as well as with their manufacturers and sales teams. In addition, extensive desk research on the capabilities and characteristics of existing sensors has been made. ;
- Step 1.3: Establish a comparable basis. With the help of the information gathered in steps 1.1 and 1.2, it is possible to match the NeXOS sensors to existing solutions, creating a clear comparison scheme to highlight the advancements introduced by NeXOS. The main parameters of the NeXOS instruments, as identified by the ASCS, are the building blocks of this comparison exercise. The result of this final step serves as input for subsequent phases.

FIGURE 3.2 THE STEPS OF THE FIRST PHASE OF THE METHODOLOGICAL FRAMEWORK



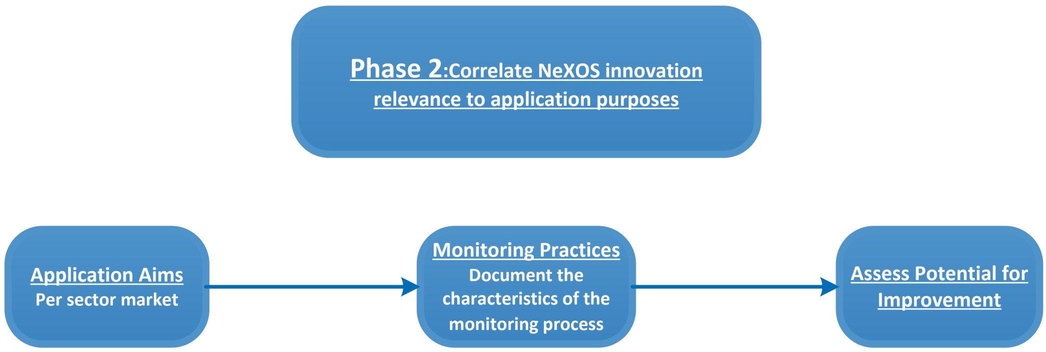
Since the NeXOS sensors are still in the development phase, an iteration loop is applied, revising step 1.1 with the updated inputs regarding sensor development progress as collected for the ASCS. This ensures that the latest developments are taken into account when constructing the comparison basis. As the development of the NeXOS innovations is ongoing throughout the duration of this task, this iteration loop is deemed necessary in order for this assessment to be up-to-date and valid. Actions taken during this iteration loop include additional consultations with project partners, interviews with manufacturers of both NeXOS and competition products as well as a thorough scan of documentation of other relevant research projects in order to identify information related to the sensor market and sensor value added[14]. Phase 2: Correlate NeXOS innovation relevance to application purposes

[14] Amongst the reviewed projects, specific attention was paid to the ones with the higher content proximity i.e. MARIABox, SCHeMA,

The aim of this phase is to reveal and pinpoint exactly the areas where each NeXOS sensor can generate added value. This involves understanding the current and future needs for the combination of each specific sensor market segment and application aim (henceforth: application purpose), how these are part of the current situation and then link them with the NeXOS improvement potential. Phase 2 is composed of three steps:

- Step 2.1: Mapping of the application aims for each market segment. As not all application aims are relevant to all market segments, this mapping ensures that, at a later stage, the advantages can be quantified as specifically as possible. Input from other tasks is used for this step, particularly those reported in Deliverables 3.5 and 3.6;
- Step 2.2: Document current environmental monitoring practices as well as monitoring needs that are not yet fulfilled by existing sensors. Under this step we identify the characteristics of relevant monitoring processes and methods, such as duration, intensity, type of data, sensors and platforms used etc. Following the logic of step 2.1, this analysis is performed for each application purpose. The necessary information has been gathered from literature and also obtained from interviews with NeXOS partners, while gaps were filled by approaching end users.
- Step 2.3: Assess potential for improvement. Here, the environmental monitoring needs of each application purpose are matched with the advancements brought in by the NeXOS sensors, in order to perform an initial assessment of the suitability/potential for improvements brought on by the NeXOS innovations in comparison with the size and prospect of each monitoring application. As a result, for each application purpose, the importance of the expected advancements brought by NeXOS, such as reduced size, low power consumption, low cost, better stability, greater measuring capabilities, low-fouling and advanced interoperability is displayed.

FIGURE 3.3: THE STEPS OF THE SECOND PHASE OF THE METHODOLOGICAL FRAMEWORK



3.1.2 *Phase 3: Showcase quantification of economic benefits*

Succeeding the classification of the technical aspects into more specific, market-related groups, this phase is dedicated to quantifying the benefits of the advancements brought by the NeXOS sensors. Based on the matrix of the most significant application purposes resulting from phase 2, in phase 3, a representative set of application purposes is identified, and a theoretical environmental monitoring case for each defined, for which the expected impact of the NeXOS sensors is quantified. To do this, use is made of the use cases defined under task 3.5 (see Deliverable D3,5) and the cost analysis for those made in task 3.6 (see Deliverable D3.6)The steps of this phase are:

- Step 3.1: Selection of application purposes: Initially, a set of application purposes is selected to showcase the potential impact of the introduction of NeXOS sensors. This set will steer towards the selection of application purposes with considerable monitoring activity, however a balance will need to be kept for application purposes between mature and emerging or between small and large market segments and between application purposes correlated with the various NeXOS innovations;
- Step 3.2: Activity-based analysis of the showcases: This step initiates the identification of the activities undertaken during the environmental monitoring life-cycle for each of the selected showcases. This draws input from the interviews and data collection tools used in Step 2.2.

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Consequently, an assessment is performed of how these activities (for each application purpose) are influenced by sensor and platform attributes and especially by the monitoring attributes that are potentially influenced by the introduction of the NeXOS sensors;

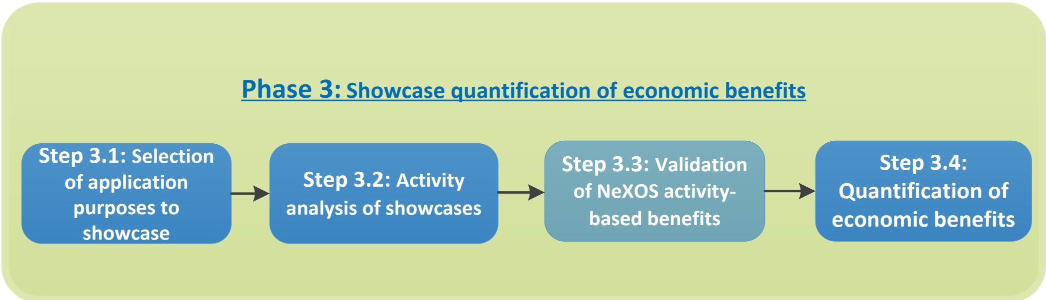
- Step 3.3 (optional): Validation of economic benefits potential. This step aims in validating the correlation of economic benefits generated for each activity of the monitoring process to the NeXOS innovations. This validation can be performed by means of expert reflection, either through structured interviews with application experts (from within the consortium), or by short interviews with potential end users approached either via NeXOS partners or during dissemination events;
- Step 3.4: Showcase economic benefits of NeXOS sensors. The aforementioned showcases can be used to identify the economic value of exploiting NeXOS innovations by estimating the activity-level impacts. The activity analysis that has been conducted for the showcases will be used to quantify the economic benefits generated by the application of the NeXOS sensors.

An indicative list of such economic benefits can include:

- Reduction in maintenance costs;
- Time savings in operating monitoring systems;
- Time savings in setting up monitoring systems;
- Reduced costs from data transmission;
- Cheaper sensors;
- Less energy consumption, power-related costs;
- Lower maintenance needs and repair costs;
- More efficient usage of platforms;
- Reduced application development costs;
- Less training needed;
- Reduced integration costs and time.

Furthermore, other advantages that might not be quantifiable e.g. improved measuring accuracy, additional parameters monitored etc. will also be identified and presented.

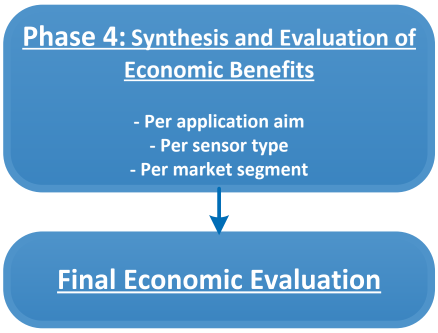
FIGURE 3.4 THE STEPS OF THE THIRD PHASE OF THE METHODOLOGICAL FRAMEWORK



3.1.3 *Phase 4: Synthesis and evaluation of economic benefits*

The fourth and final phase of the methodology incorporates the synthesis of the quantified findings in the previous phase, providing a complete picture of the value of the NeXOS sensors advantages. The scale of the overall NeXOS economic benefit potential for the application purposes of the showcases is initially assessed. Consequently, the findings of D2.1 regarding application aim and market segments characteristics can be utilised to extrapolate the economic benefits assessed to the remaining application purposes and market segments. Following the logic in previous phases and according to the distinction that has already been made, the quantified advantages can be grouped per market segment, application aim and per sensor type (e.g. optical, passive acoustic etc.). This allows this methodology to react faster to various institutional, industry and market changes by adjusting only the affected areas. The methodology concludes with the output, the final economic evaluation that considers also the unquantifiable impacts of the NeXOS sensors and leads to the assessment of the expected market uptake.

FIGURE 3.5: THE STEPS OF THE FOURTH PHASE OF THE METHODOLOGICAL FRAMEWORK



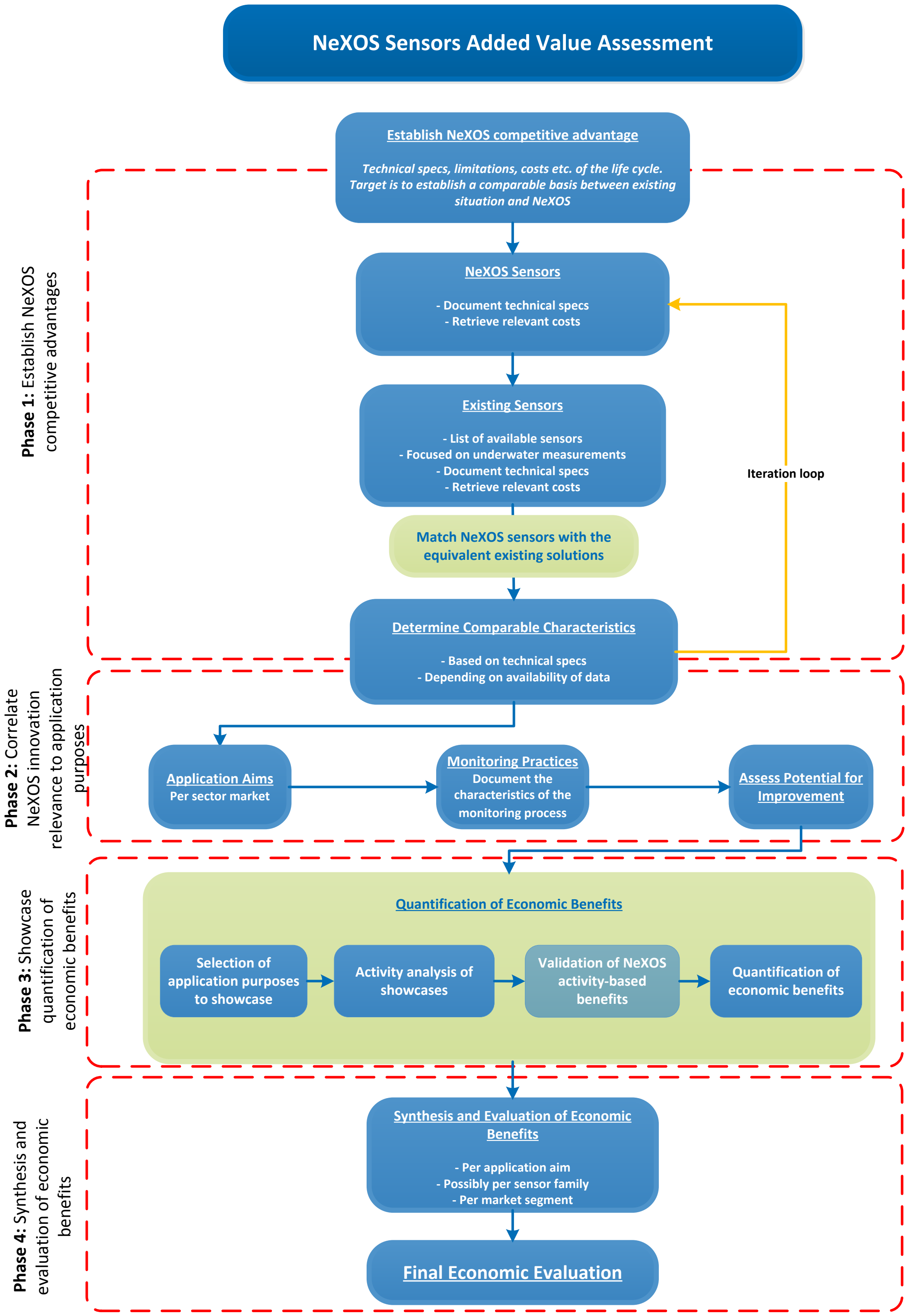
3.2 Chapter conclusion

In this chapter, a thorough analysis of the methodological framework for the assessment of the added value of the NeXOS innovation has been made. The innovations that are taken into account are:

- Optical sensor 1 (O1): a compact low-power multifunctional optical sensor system based on multi-wavelength fluorescent technology, providing detailed information on water constituents as well as other relevant contaminants being optically active in the respective spectral region;
- Optical sensor 2 (O2): a compact low-power multifunctional optical sensor system based on hyperspectral cavity absorption technology, enabling measurement of water constituents like dissolved organic matter, suspended matter, and phytoplankton;
- Optical sensor 3 (O3): a Compact low-power multifunctional carbon sensor system. These sensor arrays will quantify the marine carbonate system through the combination of a high precision spectrophotometric pH and carbonate ion sensor and a membrane based pCO_2 sensor;
- Passive acoustic sensor 1 (A1): a compact low-power multifunctional passive acoustics sensor system, enabling on-platform measurement and characterisation of underwater noise and several soundscape sources, aimed for platforms with limited autonomy and/or communication capability;
- Passive acoustic sensor 2 (A2): a compact multifunctional passive acoustics sensor system, enabling real-time waveform streaming for the measurement of underwater noise and several soundscape sources, aimed for platforms with unlimited autonomy and/or communication capability;
- Transversal innovation 1, sensor anti-fouling: an innovative, low-power, highly efficient and with minimal environmental impact scheme using active protection, controlling biocide generation with a biofilm sensor;
- Transversal innovation 2, interface interoperability: a Smart Electronic Interface for Sensor Interoperability (SEISI) that will provide a multifunctional interface for many types of current sensors and instruments, as well as for the new multifunctional sensors developed within the NeXOS project;
- Transversal innovation 3, data interoperability: a sensor web architecture with suitable web services and tools, implemented and packaged as a toolbox for deployment in different ocean observing systems.

In order to come up with the economic added value of the benefits brought by these innovations and to cover the scope and definition of the matter within the NeXOS envelope, a four-step assessment methodology has been developed as shown in Figure 3.6, and will be applied in the following chapters.

FIGURE 3.6 SCHEMATIC REPRESENTATION OF THE ADDED VALUE ASSESSMENT METHODOLOGY



4. ACHIEVEMENTS OF THE ASCS

This chapter presents the progress made during the NeXOS project in realising a set of innovations aiming to bring high added value to the EU marine environmental monitoring sector. The innovation development process has been closely monitored by the Subcommittee for the Advancement of Small and Medium Enterprise Competitiveness (ASCS), a subcommittee set up within the NeXOS consortium, aiming to maximise the added value of the end products. The process of ASCS engagement in the project is presented in Section 4.1. In this process a set of success indicators has been applied to track the progress in the development of the innovations. The achievements of the NeXOS innovations development process are presented in Section 4.2.

4.1 Stakeholder engagement to guide the achievement of added value

The NeXOS project brings together different stakeholder groups in a combined effort to produce innovations that maximise the added value of the developed marine sensors. With a consortium comprising sensor and platform manufacturers, developers, integrators, researchers, end users and market experts, the need was identified to create an organisation structure that ensures a proper balance between the development priorities of each of the different stakeholders. Particularly in view of achieving innovations that create high added value for the EU marine environmental monitoring sector and to achieve high market penetration for these innovations.

The **Subcommittee for the Advancement of Small and Medium Enterprise Competitiveness (ASCS)** is a monitoring mechanism created to ensure that the development of the NeXOS innovations keeps in line with market requirements. Details of the ASCS structure and working principles are reported upon in Deliverable 2.2. In summary, since its establishment in the first year of the NeXOS project, the ASCS has been responsible for:

- Creating a shortlist of success indicators for each of the NeXOS innovations accounting for the most important attributes from a market perspective;
- Setting challenging but attainable aims (targets) for each of the success indicators;
- Steering the innovation development process by updating the aims and success indicators according to market developments when necessary;
- Periodically monitoring progress on the set of success indicators;
- Evaluating progress made on achieving the aim set for each of the success indicators;
- Calling for focus on success indicators where development is lacking;
- Evaluating the attainability of the existing aims and setting alternative aims if necessary trying not to compromise the added value of the innovations;

To ensure that the NeXOS project goals are achieved and that they are aligned with the interests of the SMEs, the ASCS consists of 2 main groups of partners: i) industrial partners, and ii) NeXOS project officials. Further in the meetings of the ASCS, the Work Package Leaders (WPLs) of the innovation Work Packages, who are not members of the ASCS, have been invited to explain the progress achieved, reasons relating to their choices made and discuss and agree with the ASCS suggestions for steering the innovation process. Table 4-1 provides an overview of the members of the ASCS.

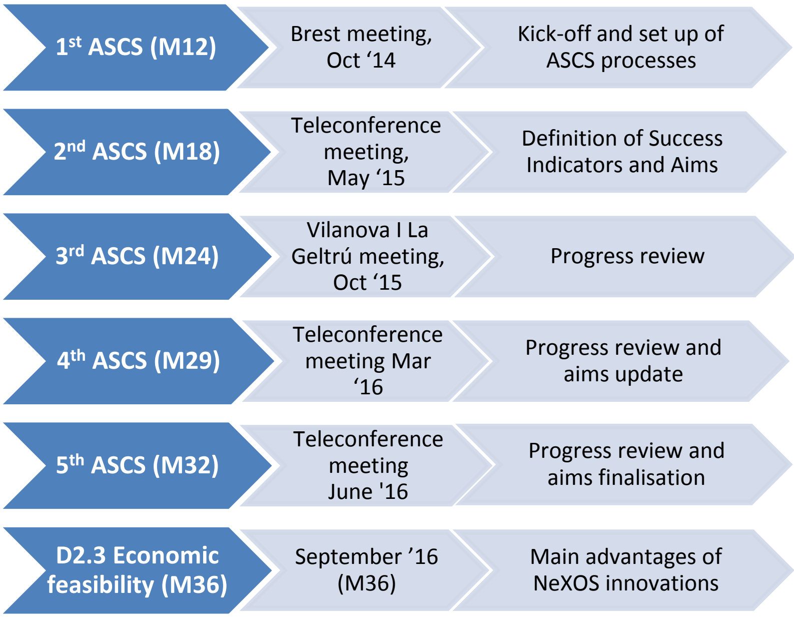
TABLE 4-1 ASCS MEMBERS

Stakeholder group	Role	Partners
Industrial	- Optic sensor manufacturers - Acoustic sensor manufacturers - EAF manufacturers - Platform manufacturers	- TRIOS - FRANATECH - SMID - NKE - ALSEAMAR

Stakeholder group	Role	Partners
NeXOS project officials	- Project Coordinator - Project Chief Scientist - Project Chief Engineer - Lead for Dissemination and Outreach - ASCS Chair and coordinator	- PLOCAN - MARUM - IFREMER - IEEE - ECORYS

The ASCS adopted an iterative approach to secure a continuous and rigorous monitoring on of the innovation development process and constant progress in reaching the aims set for the success indicators. In this respect a series of 5 ASCS meeting have been planned and conducted since the beginning of Task 2.3: (Added Value of NeXOS innovations) in Month 10. As the development process has matured throughout the progress of the project, the ASCS has increased the frequency of its meetings aiming to more closely monitor the development process becomes more critical towards the end of the innovation process. Figure 4.14.1 presents the sequence of ASCS meetings conducted, the means used and the main goals while advancing towards finalising Deliverable 2.3.

FIGURE 4.1: OVERVIEW OF ASCS MEETINGS



The ASCS adopted a uniform and straight forward procedure in order to minimise burden on the developers of the innovations and to assure that the inputs received and the evaluations provided are consistent for all innovations.

Pre-meeting procedure

The steps taken in preparation of the ASCS meeting include:

1. The ASCS chair initiated the process by preparing the success indicator list for each of the NeXOS innovations and distributing it to the innovation WPLs to complete further. After the 2nd meeting this step also included an assessment of the progress made on the aims set for the success indicators during the previous ASCS meeting. The primary sources of information were the most recently available project deliverables. This input was structured in the success indicator tables (see Annex A);
2. The innovation WPLs updated the success indicator list highlighting the progress made on achieving the set of aims while if relevant making suggestions for updating these aims. Afterwards they communicated these updates to the ASCS chair;
3. The ASCS chair then arranged bilateral short telephone meetings with the WPLs 2-3 weeks before each ASCS meeting to discuss their inputs as well as any interesting findings that can be of use for the industrial partners;

4. Finally, the ASCS chair formed an initial evaluation of the progress made on each success indicator. A relevant presentation was then distributed to the ASCS members for their preparation of the meeting.

ASCS meeting procedure

Steps during the ASCS meetings:

1. The ASCS chair scheduled each meeting with all ASCS members and the relevant WPLs. During each meeting, which was split into sessions per set of innovations (i.e. Transversal, O1+O2+O3, A1+A2, EAF), the presentation of the ASCS findings per innovation took place with the attendance of the relevant partners;
2. The ASCS members were invited to reflect on the presentation and confirm the evaluation for the progress in achieving each success indicator aim. Also, they were invited to provide their assessment of the pertaining relevance of the indicators and aims;
3. For the success indicators where the progress was evaluated as being critical for the achievement of the aims, the WPLs were invited to indicate how they proposed to proceed while the ASCS members could suggest alternative aims and trade-offs taking into account the market relevance of the innovation attributes;
4. The ASCS members and WPLs agreed on the updated aims for each indicator and to trade-offs where necessary to retain the competitive advantage of the innovation when the aims are considered not attainable.

For the evaluation of the progress towards achieving the aims set for each success indicator, a simple “traffic-light” concept was adopted, consisting of a 7-brackets scale giving assessments ranging from “Above target” to reflect an overachievement of the aim set, to “Redefine goal” to reflect that an aim has been assessed as being unattainable and thus a new aim is needed. Table 4-2 explains the meaning of each assessment ranking.

TABLE 4-2: TRAFFIC-LIGHT EVALUATION SCHEME

Above target	Achieved and can improve	Achieved	On track	Focus needed	Challenging	Redefine goal
The aim has been achieved and surpassed	The aim has been achieved and further improvement is possible and relevant	The aim has been achieved	Innovation development is on track of achieving the aim according to planning	Some corrective action(s) is needed in order to achieve the given aim	Significant corrective action(s) is needed in order to achieve the given aim	Aim is considered unattainable and should be redefined

Post-meeting procedure

Steps after the conclusion of each ASCS meeting:

1. In the time following the conclusion of the ASCS meeting, the WPLs were given the opportunity to update their progress on the success indicator aims and clarify the corrective actions agreed;
2. The ASCS chair then made any final modifications updating the evaluation of the innovations in the success indicator table. The innovation WPLs were then notified of the decisions on the updated set of success indicator aims in accordance with the ASCS meeting.

Overall, the aim of the ASCS mechanism has been to assure that, despite the unpredictable nature of innovation development, the NeXOS innovations developed under rigorous monitoring and assuring that a flexible approach was adopted when dealing with unpredictable outcomes and development failures.

4.2 Improvements generated through the ASCS process

The ASCS procedure as described in the previous section has been iteratively applied to update the "traffic-light" evaluation of the progress made in reaching the success indicators for each of the NeXOS innovations. This ASCS approach has been useful in bringing the NeXOS innovations to a development state where they produce added value, by reaching a combination of attributes that enhances their performance in comparison with the pre-NeXOS state of play. In the following sections, the main improvement areas for each of the NeXOS innovations are presented per innovation set:

- Optical sensors (O1, O2 and O3);
- Acoustic sensors (A1 and A2);
- EAF;
- Transversal innovations (system and data interoperability and antifouling).

Although the transversal innovations bring added value also to the other innovation series and can be considered some of the main improvement areas for all innovations, the achievements in this area are presented separately.

Optical sensors

Concerning the set of optical sensors, the focus of the NeXOS innovation process has been concentrated on enabling multifunctional sensors to measure multiple parameters in parallel while at the same time improving a number of sensor attributes. The main areas of improvement, relevant for the whole series of optical sensors, as targeted by the ASCS, are:

- Reducing the size of the sensors;
- Reducing their power consumption;
- Achieving market acceptable (lower) Capital and Operational costs;
- Allowing to combine the measurement of multiple parameters;
- Achieving a higher range of operation (time, water depth); and
- Achieving a high measurement accuracy.

Additional improvement areas for the sensors of this series that have been targeted by the NEXOS innovation process include increasing the response time of measurement cycles and increasing the long term stability of the measurements.

The ASCS process, beyond setting the development targets and monitoring their achievement, was also critical in realising the need to create different versions of the O3 sensor, enabling it for different monitoring platforms, due to the fact that the achievement of the original size aim proved unattainable.

Passive acoustic sensors

Regarding the set of passive acoustic sensors, the focus of the NeXOS innovation process has also been concentrated in enabling the sensors to measure multiple parameters while at the same time improving a number of their attributes. The main areas of improvement, relevant for the whole series of passive acoustic sensors, as targeted by the ASCS were:

- Reducing the size of the sensors;
- Reducing their power consumption;
- Allowing to combine the measurement of multiple parameters;
- Reducing the communication load;
- Achieving market acceptable (lower) Capital and Operational costs;
- Increasing the measurement sensitivity;
- Achieving a high operational depth;
- Achieving an omnidirectional beam pattern;

- Increasing sensor reliability;
- Enabling the sensor for multiple platforms.

Additional improvement areas for the sensors of this series that have been targeted by the NEXOS innovation process include integrating ancillary variable measurement.

The ASCS process, beyond setting the development targets and monitoring their achievement, has also realised the creation of alternative versions of the A1 and A2 sensors, enabling increased operational depths against additional manufacturing costs. Additionally, the power consumption indicator was deemed irrelevant for the A2 sensor.

EAF

In steering the innovation process for the EAF innovation, the focus of the ASCS has been concentrated on the main areas of improvement:

- Reducing the size of the sensors;
- Allowing to combine the measurement of multiple parameters;
- Achieving a high range of operation;
- Achieving a high measurement accuracy;
- Achieving a high operational depth;
- Achieving a high operational temperature;
- Increasing battery duration and memory storage;
- Reducing sensor response time;
- Achieving market acceptable (lower) Capital and Operational costs;
- Increasing the system robustness; and
- Decreasing measurement drift.

The ASCS process, beyond setting the development targets and monitoring their achievement, has also been critical in realising the need to redefining and rationalising the goals of the development process when considered unattainable. Most importantly the ASCS process was critical in identifying and highlighting the success indicators still in need of improvement and steering the attention of the development team accordingly.

Transversal innovations

This set of innovations is split into the 3 distinct NeXOS innovations. These concern the Antifouling protection, the interface interoperability and the data interoperability. The ASCS dealt separately with the achievements of these 3 Innovations, although progress in achieving their goals constituted a large part of the added value of the individual sensor innovations described in the previous sections. The main areas of improvement for the transversal innovations have been summarised in the following success indicators for each of the innovations.

In the field of the **antifouling protection innovation**, the focus of the ASCS has been in:

- Achieving a size that allows application to existing sensors;
- Reducing power consumption;
- Defining market acceptable Capital and Operational costs;
- Increasing antifouling duration.

Concerning **interface interoperability** of the sensors, the focus of the ASCS has been in:

- Enabling plug-and-play for all NeXOS sensor innovations;
- Achieving a low power consumption;
- Implementing the OGC-PUCK protocol;
- Introduce elements reducing the costs of mounting sensor to platforms;
- Increase the reliability of the interface;
- Increase compatibility with available sensor systems; and
- Enable sensor web integration.

Concerning **data interoperability**, the focus of the ASCS has been in:

- Enabling all of the NeXOS sensor systems;
- Implementing OGCIT standards (SWE) and integrating sensors;
- Adopt an efficient communication approach minimising communication costs;
- Increase the reliability of the data interface;
- Build a community of users;
- Create a best practice document on applying SWE;
- Implement GEOSS compatibility; and
- Adopt a scalable architecture.

All in all, regarding the transversal innovations, the ASCS process has been monitoring and checking the development process alongside in order to produce innovations that optimally supplement the sensor innovations created by NeXOS maximising therefore their added value.

The ASCS progress tables per innovation can found in Annex A.

5. COMPARISON WITH COMPETITION

In this chapter, the innovations developed within NeXOS will be compared against competing products that are already available on the market and that provide similar capabilities. This comparison is the backbone of Phase 1 of the assessment methodology described in Chapter 3. The following paragraphs describe the technical properties of the NeXOS innovations, next to those of the comparable competition products, starting with the passive acoustic and moving on to the optical solutions. It is noted that not all competitor suppliers disclose all relevant indicators (e.g. CAPEX and OPEX are often not published).

5.1 Passive acoustic sensors

In the following paragraphs of this chapter, the two passive acoustic innovations developed in NeXOS are examined in contrast to other comparable products in the market. The technical properties of each available product is presented, in order to highlight the differences and potential advantages of the NeXOS acoustic innovations.

5.1.1 *Innovation A1 and the competition*

The NeXOS A1 innovation is described as a compact, low-power, multifunctional passive acoustics sensor system, enabling on-platform measurement and characterisation of underwater noise and several soundscape sources, aimed for platforms with limited autonomy and/or communication capability. In essence, A1 is a digital hydrophone of which the size, data interface capabilities and power consumption make it ideal for use with multiple types of platforms where undisturbed power supply is not guaranteed. The NeXOS A1 comes with some unique features including real-time embedded spectral analysis, noise statistics and detection as well as an open-source firmware. The operational costs for A1 are based on the use case and cost analysis presented in Deliverable 3.6. This use case foresees a monitoring network of (at least) 10 PROVOR Argo floats being equipped with A1 sensors. As such, OPEX includes set-up, calibration, maintenance, personnel as well as data management and transmission costs for one sensor-float pair. The core technical characteristics of the NeXOS A1 sensor can be seen in Table 5-1:

TABLE 5-1: TECHNICAL CHARACTERISTICS OF NEXOS A1 SENSOR

Sensor name Parameter	NeXOS A1
Size:	255x35.5 mm
Weight:	0.350 – 0.250 Kg
CAPEX:	€ 4,000
OPEX:	€ 6,500/year
Power Consumption:	<1000 mW operating, 30mW sleep mode
Depth:	3000 m
User frequency rate:	Up to 100kS/s (selectable)
Sensitivity:	-138/158/178 dB
Beam pattern:	Omnidirectional

Sensor name Parameter	NeXOS A1
Platforms:	Glider, profiler, buoy, AUV, ROV
Accuracy:	+-1.5 dB
Plug and play	Yes (OGC-PUCK)
Interface	Ethernet, Serial, OGC-SWE
Battery life	-

In order to have a valid comparison, a market search has been conducted to reveal any other products existing in the underwater passive acoustic sensor market that can fit the profile and capabilities of the NeXOS A1. This immediately limited the search to only digital hydrophones, as comparing analogue solutions would be invalid on many levels. The market research revealed six solutions comparable to A1. These are:

- The icListen HF by OceanSonics;
- The DHP8502 by Sunfull;
- The EHyd HF by Naxys;
- The digitalHyd SR-1 by Marsensing;
- The DT-402D(V) by SMID; and
- The DH2-24/48M by Hinz.

These competition solutions will be further analysed in the following paragraphs.

OceanSonics, a Canadian designer and manufacturer of digital hydrophones operating out of Nova Scotia, offers a range of digital hydrophones that are perceived as of very high quality. The icListen Hydrophone is a compact instrument that allows for logging of calibrated waveforms, spectral or event data in a standard format (wav). It can be used as a digital hydrophone and/or acoustic data logger. According to the manufacturer, the icListen is targeting applications such as environmental monitoring, ambient noise measurement, marine renewable energy, pipeline leak detection, ocean observatories, marine mammal monitoring and ocean noise measurement. In order to fit better in comparison with the NeXOS A1 sensor, the HF version of the icListen hydrophone was selected for the comparison. Table 5-2 shows the technical specifications.

TABLE 5-2: TECHNICAL CHARACTERISTICS OF OCEANSONICS ICLISTEN HF

Sensor name Parameter	icListen HF Titanium
Size:	267x48 mm
Weight:	0,96 kg
CAPEX:	€ 10,000
OPEX:	-
Power Consumption:	2W
Depth:	3500m
User frequency rate:	10-100kHz

Sensor name Parameter	icListen HF Titanium
Sensitivity:	-170dB
Beam pattern:	Omnidirectional
Platforms:	Glider, profiler, buoy, AUV, ROV
Frequency accuracy:	-
Plug and play	Yes
Interface	Ethernet, FTP, USB, Web browser access
Battery life	10 hours

Another competitor product comes from Sunfull, a Chinese hi-tech equipment manufacturer. Sunfull is a relatively small but fast growing SME with a 15-year presence in the global market, also active in the cable and connector manufacturing scene. According to the manufacturer, the DHP85 series digital hydrophone is particularly suitable for applications in ocean/environmental monitoring and is highly customizable per user request. Another important characteristic of this particular product is that the company claims full ownership of the IP regarding the instrument, a fact that makes this product a great comparison with the NeXOS A1 on more levels than just technical. Table 5-3 shows the technical specifications of the product.

TABLE 5-3: TECHNICAL CHARACTERISTICS OF SUNFULL DHP8502

Sensor name Parameter	Sunfull DHP8502
Size:	250x43
Weight:	-
CAPEX:	-
OPEX:	-
Power Consumption:	3W
Depth:	-
User frequency rate:	20kHz
Sensitivity:	-210dB
Beam pattern:	Omnidirectional
Platforms:	Glider, profiler, buoy, AUV, ROV
Frequency accuracy:	-
Plug and play	-

Interface	RS232
Battery life	-

The next competing instrument comes from Naxys, a Norwegian high-tech manufacturer that is mostly active in the oil & gas industry, providing solutions regarding subsea acoustic leak detection, structural monitoring as well as subsea machinery and process monitoring. One of their products is the Naxys Ehyd digital hydrophone, which fits the Nexos A1 profile, as it can be used in oceanography and marine research applications. Furthermore, the Ehyd features also one of the main advantages of the A1, plug and play capability. Much like the NeXOS sensor, the Ehyd has Ethernet interface and stores data in. wav format, making it possible for the user to connect the hydrophone to a pc easily and use the data as necessary. Table 5-4 shows the technical specifications of this particular instrument.

TABLE 5-4: TECHNICAL CHARACTERISTICS OF THE NAXYS EHYD HF

Sensor name Parameter	NAXYS EHyd HF
Size:	250x70
Weight:	0,9 kgs
CAPEX:	-
OPEX:	-
Power Consumption:	-
Depth:	500m
User frequency rate:	1 to 65 kHz
Sensitivity:	-211dB
Beam pattern:	Omnidirectional
Platforms:	Glider, profiler, buoy, AUV, ROV
Frequency accuracy:	-
Plug and play	Yes
Interface	Ethernet, Web browser configuration
Battery life	-

Another manufacturer that produces competing products is Marsensing, a relatively new company based in Portugal, specialized in marine sensing and underwater acoustic technologies. More specifically, Marsensing has developed digitalHyd SR-1, a digital hydrophone targeted towards underwater noise monitoring, marine mammals bioacoustics and underwater acoustics research. Table 5-5 shows the characteristics of the instrument.

TABLE 5-5: TECHNICAL CHARACTERISTICS OF THE MARSENSING DIGITALHYD SR-1

Sensor name Parameter	MARSENSING digitalHyd SR-1
Size:	323x50
Weight:	0,77 kgs
CAPEX:	-
OPEX:	-
Power Consumption:	-
Depth:	100m
User frequency rate:	50 kHz
Sensitivity:	-162.2dB
Beam pattern:	-
Platforms:	Glider, profiler, buoy, AUV, ROV
Frequency accuracy:	-
Plug and play	-
Interface	USB
Battery life	12 hours continuous acquisition 500 hours standby

SMID technology, an Italian manufacturer and also partner in the NeXOS project, has developed another digital hydrophone that can be competitive to the NeXOS A1. The DT-402D is a digital hydrophone aimed towards scientific applications and is one of the few competition instruments that can be operated in comparable to the A1 depth. Table 5-6 contains the relevant technical characteristics. The company was not willing or able to disclose cost data.

TABLE 5-6: TECHNICAL CHARACTERISTICS OF THE SMID DT-402D(V)

Sensor name Parameter	SMID DT-402D(V)
Size:	-
Weight:	-
CAPEX:	-
OPEX:	-
Power Consumption:	-
Depth:	3000m

Sensor name Parameter	SMID DT-402D(V)
User frequency rate:	10 to 48 kHz
Sensitivity:	-202dB
Beam pattern:	Omnidirectional
Platforms:	(power supply necessary)
Frequency accuracy:	-
Plug and play	-
Interface	Ethernet, Coaxial, USB
Battery life	No battery

The last competing product comes from HINZ Messtechnik, a German engineering company that, besides developing instruments, provides consulting and maintenance services. More specifically, the DH2-24/48M is a hydrophone with build-in A/D Converter and digital audio transmitter, suitable for applications similar to those targeted by the NeXOS A1. Nevertheless, the solution from Hinz is limited depth-wise as the digital audio signal standard used (AES/EBU) cannot be transmitted through the current cable for such long distances. Regardless, this product is included in the comparison in order to highlight the advancements against competitor products. Table 5-7 shows the main technical characteristics of this instrument.

TABLE 5-7: TECHNICAL CHARACTERISTICS OF THE HINZ DH2-24/48M

Sensor name Parameter	HINZ DH2-24/48M
Size:	270x36
Weight:	-
CAPEX:	€ 7,000
OPEX:	-
Power Consumption:	0.36 W
Depth:	100m
User frequency rate:	1 to 15 kHz
Sensitivity:	-203dB
Beam pattern:	-
Platforms:	-
Frequency accuracy:	-
Plug and play	-

Sensor name Parameter	HINZ DH2-24/48M
Interface	SPDIF
Battery life	>24 hours continuous operation

Out of the six products identified as potentially competing with A1, only three are capable of straight comparison as is, namely the icListen HF Titanium, the NAXYS Ehyd HF and the SMID DT-402D(V). Table 5.8 provides a full comparison between A1 and all of the competing solutions that were found in the market.

As it is evident from the comparison table, the NeXOS A1 has significant advantages over the competing products in a number of key areas. A1 performs better in the areas of size, capital expenditure, power consumption and plug and play capability. It has the smallest diameter of all compared products and a length that is very close to the minimum observed. Compared to the two main competitors, A1 has the smallest size by far. Additionally, NeXOS A1 offers the solution with the lowest price. At this point, it is necessary to point out that the CAPEX figure for NeXOS A1 is valid for the prototype and assumes that only one hundred units will be built. Therefore, the price of the A1 will drop further once the instrument is produced in larger numbers. Nevertheless, the main competitor products at this moment are 40% more expensive.

Regarding power consumption, one of the most critical attributes of any instrument of this kind, the NeXOS A1 performs much better than the competition. In comparison to the main competitor products, A1 consumes at least 50% less power, a great advantage over them as it affects operations on all levels. Finally, plug and play capability is only found in two competitor solutions that, however, are not comparable with A1 in other areas. Most competitors of A1 do not provide Plug n Play capability at this moment.

Table 5-8: Comparison between the NeXOS A1 and the competition products

Sensor name Parameter	NeXOS A1	icListen HF Titanium	Sunfull DHP8502	NAXYS EHyd HF	MARSENSING digitalHyd SR-1	SMID DT-402D(V)	HINZ DH2-24/48M
Size:	255x35.5	267x48	250x43	250x70	323x50	-	270x36
Weight:	0.350 – 0.250 Kg	0,96 kgs	-	0,9 kgs	0,77 kgs	-	-
CAPEX:	€ 4,000	€ 10,000	-	-	-	-	€ 7,000
OPEX:	€ 6.500	-	-	-	-	-	-
Power Consumption:	<1000 mW operating, 30mW sleep mode	2W	3W	-	-	-	0.36 W
Depth:	1500 m	3500m	-	500m	100m	3000m	100m
User frequency rate:	Up to 100kHz (selectable)	10-100kHz	20kHz	1 to 65 kHz	1 to 51.6 kHz	10 to 48 kHz	1 to 15 kHz
Sensitivity:	-138/158/178 dB	-170dB	-210dB	-211dB	-162.2dB	-202dB	-203dB
Beam pattern:	Omnidirectional	Omnidirectional	Omnidirectional	Omnidirectional	-	Omnidirectional	-
Platforms:	Glider, profiler, buoy, AUV, ROV	Glider, profiler, buoy, AUV, ROV	Glider, profiler, buoy, AUV, ROV	Glider, profiler, buoy, AUV, ROV	Glider, profiler, buoy, AUV, ROV	-	-
Plug and play	Yes	Yes	-	Yes	-	-	-
Interface	Ethernet, Serial, OGC-SWE	Ethernet, FTP, USB, Web browser access	RS232	Ethernet, Web browser configuration	USB	USB	-
Battery life	-	10 hours	-	-	12 hours continuous acquisition	No battery	>24 hours continuous operation

5.1.2 *Innovation A2 and the competition*

The NeXOS A2 innovation is defined as a compact multifunctional passive acoustics sensor system, enabling real-time waveform streaming for the measurement of underwater noise and several soundscape sources, aimed for platforms with unlimited autonomy and/or communication capability. In essence, A2 is an array of passive acoustic sensors, synchronized so as to work together and provide additional functionalities such as detection of the sound's direction of arrival. More specifically, A2 is an array of four A1 digital hydrophones coupled to a main unit.

Therefore, in order to have a valid comparison with the competition, it is necessary to identify the competing solutions that can be operated in an array configuration. The market research revealed three such solutions namely:

- The icListen HF by OceanSonics;
- The EHyd HF by Naxys; and
- The DH2-24/48M by Hinz.

Since the hydrophones and sensors used to create these arrays are identical to the single devices that were covered previously, the advantages or disadvantages of A2 remain the same as those of A1, but multiplied by the number of sensors used in an array. Table 5-9 provides a full comparison between A2 and all of the competing solutions that were found in the market. Again, as also concluded for A1, NeXOS A2 proves to be most attractive financially, while performing equally well or better than competition on size and power use.

TABLE 5-9: COMPARISON BETWEEN THE NEXOS A2 AND THE COMPETITION PRODUCTS

Sensor name Parameter	NeXOS A2	icListen HF Titanium	NAXYS EHyd HF	HINZ DH2-24/48M
Size:	255x35.5	267x48	250x70	270x36
Weight:	Depending on configuration	Depending on configuration	Depending on configuration	Depending on configuration
CAPEX:	Around € 25.000	Around € 40.000	-	-
OPEX:	-	-	-	-
Power Consumption:	<1000 mW operating, 30mW sleep mode	2W	-	0.36 W
Depth:	1500 m	3500m	500m	100m
User frequency rate:	50kHz (selectable)	10-100kHz	1 to 65 kHz	1 to 15 kHz
Sensitivity:	-138/158	-170dB	-211dB	-203dB
Beam pattern:	Omnidirectional	Omnidirectional	Omnidirectional	-
Platforms:	Glider, profiler, buoy,	Glider, profiler,	Glider, profiler,	-

Sensor name Parameter	NeXOS A2	icListen HF Titanium	NAXYS EHyd HF	HINZ DH2-24/48M
	AUV, ROV	buoy, AUV, ROV	buoy, AUV, ROV	
Frequency accuracy:	-	-	-	-
Plug and play	Yes	Yes	Yes	-
Interface	Ethernet, USB	Ethernet, FTP, USB, Web browser access	Ethernet, Web browser configuration	-
Battery life	-	10 hours	-	>24 hours continuous operation

5.2 Optical sensors

In the following paragraphs of this chapter, the three optical innovations developed in NeXOS are examined in contrast to other comparable products in the market. The technical properties of the products will be presented on both sides, in order to highlight the differences and potential advantages of the NeXOS optical innovations.

5.2.1 *Innovation O1 and the competition*

The NeXOS O1 innovation is defined as a compact, low-power, multifunctional optical sensor system based on multi-wavelength fluorescent technology, providing detailed information on water constituents as well as other relevant contaminants being optically active in the respective spectral region. The O1 sensor measures four parameters, namely coloured dissolved organic matter (CDOM), Chlorophyll-a, polycyclic aromatic hydrocarbons (PAH) and Turbidity. The main technical characteristics of the NeXOS O1 sensor can be seen in Table 5-10.

TABLE 5-10: TECHNICAL CHARACTERISTICS OF NEXOS O1 SENSOR

Sensor name Parameter	NeXOS O1
Size:	196x36 mm (lxd)
Weight:	0.5 kgs
CAPEX:	€ 10,000
OPEX:	€ 500/year
Power Consumption:	2500 mW
Depth:	2000 m
Measured Parameters:	4 (CDOM/Chloroph-a/PAH/Turbidity)

Sensor name Parameter	NeXOS O1
Range Tryptophan:	0-500 ppb
Range fDOM:	0-200 ppb
Range Phenantrene:	0-50,0-500 µg/L
Accuracy Tryptophan:	<0.2 ppb
Accuracy fDOM:	<0.2 ppb
Accuracy Phenantrene:	<0.2,<1 ppb
Response time:	<5 sec

Finding a competing sensor on the market that measures exactly the same parameters proved an impossible task, making the O1 a unique product in that sense. However, there are other solutions that measure different parameters and, if combined, can create an alternative solution that matches, at least, the capabilities of the NeXOS O1 sensor. Ten such sensors were identified to be available on the market, namely:

- The Contros HydroC PAH Subsea Fluorometer;
- The Wetlabs ECOS FL;
- The Chelsea Tech. UviLux sensor;
- The Seapoint Ultraviolet Fluorometer;
- The Turner Designs C3 Fluorometer and Cyclops-7;
- The YSI EXO fDom;
- The TriOS microFlu CDOM;
- The Valeport Hyperion; and
- The bbe-moldaenke FluoroProbe.

These competing solutions are further analysed in the following paragraphs.

The first competition sensor comes from Contros, a German designer and manufacturer of underwater chemical sensors, recently acquired by Kongsberg. Their sensor, HydroC PAH Subsea Fluorometer, can detect PAH in depths up to 6000 m, depending on the chosen housing. Furthermore, it supports real-time data visualization and features an antifouling system with nano-coating on the optical lens which, according to the manufacturer, prevents fouling altogether. Besides PAH, a parameter that it has in common with O1, HydroC PAH measures three additional parameters. Table 5-11 shows the technical characteristics of this product.

TABLE 5-11: TECHNICAL CHARACTERISTICS OF HYDROC SUBSEA FLUOROMETER

Sensor name Parameter	HydroC Subsea Fluorometer
Size:	320x75 (lxd)
Weight:	4.8kgs
CAPEX:	€-4,500
OPEX:	-
Power Consumption:	3 W

Sensor name Parameter	HydroC Subsea Fluorometer
Depth:	6000m
Measured Parameters:	4 (humic acids, amino acids, BTXE, PAH)
Range Tryptophan:	-
Range fDOM:	-
Range Phenantrene:	0-50, 0-500 µg/L
Accuracy Tryptophan:	-
Accuracy fDOM:	-
Accuracy Phenantrene:	0.1 ppb
Response time:	-

WetLabs (now known as Sea Bird Scientific) manufactures the second competing product, the ECO FL series. This series of single channel fluorometers comes in a wide variety of capabilities, as per user needs. For the purposes of this comparison, the configuration that is closest to O1 will be used, measuring CDOM and PAH among other parameters. It is worth mentioning that this solution does not include antifouling protection, which comes with bio-wipers at an extra cost. Moreover, a choice has to be made between real-time data output and memory card storage. Table 5-12 shows the technical characteristics of this product.

TABLE 5-12: TECHNICAL CHARACTERISTICS OF ECO FL

Sensor name Parameter	ECO FL
Size:	127x63 (lxd)
Weight:	0.4kgs
CAPEX:	\$6,500 - \$9,500 (appr. € 6,000-9,000)
OPEX:	-
Power Consumption:	0.8 W
Depth:	600m/6000m
Measured Parameters:	6 (chlorophyll-a, CDOM, uranine, rhodamine, phycoyanin, phycoerythrin)
Range Tryptophan:	-
Range fDOM:	0-500 ppb
Range Phenantrene:	-
Accuracy Tryptophan:	-

Accuracy fDOM:	0.09 ppb
Accuracy Phenantrene:	-
Response time:	-

The next competing product comes from a British design and manufacturing company, Chelsea Technologies Group. They are supplying the market with the UviLux sensor, a solution that can measure five parameters, including PAH and CDOM. Table 5-13 shows the technical characteristics of this product.

TABLE 5-13: TECHNICAL CHARACTERISTICS OF UVILUX SENSOR

Sensor name Parameter	UviLux Sensor
Size:	149x70 (lxd)
Weight:	0.8kgs
CAPEX:	-
OPEX:	-
Power Consumption:	1 W
Depth:	1000m
Measured Parameters:	5 (aromatic hydrocarbons PAH, CDOM, Truptophan-like fluorescense TLF, BOD, optical brighteners)
Range Tryptophan:	0-600 ppb
Range fDOM:	0-600 ppb
Range Phenantrene:	-
Accuracy Tryptophan:	0.01 ppb
Accuracy fDOM:	0.03 ppb
Accuracy Phenantrene:	-
Response time:	-

Seapoint Sensors, a manufacturer from the United States, has produced a range of products that includes four fluorometers and a turbidity meter. Again, there is no single solution that can match exactly the capabilities of the O1, however a combination of Seapoint's chlorophyll Fluorometer, Ultraviolet Fluorometer and Turbidity meter, three separate products, can come close. For the purposes of this comparison study, the Ultraviolet Fluorometer will be included in the comparison, as it is the single instrument that competes closest to O1. Table 5-14 shows the technical characteristics of this product.

Table 5-14: Technical characteristics of Seapoint Ultraviolet Fluorometer

Sensor name Parameter	Seapoint Ultraviolet Fluorometer
Size:	168x64 (lxd)
Weight:	0.9kgs
CAPEX:	-
OPEX:	-
Power Consumption:	0.8 W
Depth:	6000m
Measured Parameters:	3 (CDOM, crude oil, UV fluorescent dyes)
Range Tryptophan:	-
Range fDOM:	0-1500 ppb
Range Phenantrene:	-
Accuracy Tryptophan:	-
Accuracy fDOM:	0.05 ppb
Accuracy Phenantrene:	-
Response time:	-

Turner Designs, another manufacturer from the United States, provides a comprehensive range of fluorometers, relevant to the O1. More interestingly, the C3 submersive Fluorometer has the ability to incorporate three optical sensors, the choice being between turbidity, Chlorophyll, blue-green algae, fluorescein dye, rhodamine dye, CDOM, optical brighteners for wastewater treatment, crude oil and refined fuels. As three of the options match the capabilities of O1 (chlorophyll, CDOM, turbidity), this competing solutions is by far the most comparable product. Table 5-15 shows the technical characteristics of this product.

Table 5-15: Technical characteristics of C3 Submersive Fluorometer

Sensor name Parameter	C3 Submersive Fluorometer
Size:	230x100 (lxd)
Weight:	1.64kgs
CAPEX:	€ 9,500
OPEX:	-
Power Consumption:	2.4 W

Sensor name Parameter	C3 Submersive Fluorometer
Depth:	600m
Measured Parameters:	3 (CDOM, Chlorophyll, Tubidity)
Range Tryptophan:	20000 ppb
Range fDOM:	0-1250 ppb
Range Phenantrene:	-
Accuracy Tryptophan:	3 ppb
Accuracy fDOM:	0.15 ppb
Accuracy Phenantrene:	-
Response time:	-

TriOS, a German manufacturer and also partner in the NeXOS project, produces a range of optical solutions under the microFlu brand name. Within this product family, the microFlu-CDOM is the relevant product as it is the only one that measures similar parameters. Table 5-16 shows the technical characteristics of this product.

TABLE 5-16: TECHNICAL CHARACTERISTICS OF MICROFLU-CDOM

Sensor name Parameter	microFlu CDOM
Size:	217x48 (lxd)
Weight:	0.5kgs
CAPEX:	€ 3,300
OPEX:	€ 750 / year
Power Consumption:	0.2 W
Depth:	6000m
Measured Parameters:	1 (CDOM)
Range Tryptophan:	-
Range fDOM:	0-200 ppb
Range Phenantrene:	-
Accuracy Tryptophan:	-
Accuracy fDOM:	0.2 ppb
Accuracy Phenantrene:	-

Response time:	-

Valeport, a British oceanographic, hydrographic and hydrometric instrument designer and manufacturer, offers the Hyperion Fluorometer, a standalone sensor that can measure Chlorophyll-a, Fluorescein or Rhodamine depending on the user request. For the purposes of this comparison, only the version measuring Chlorophyll-a will be considered as this is a parameters that the NeXOS O1 also measures. Table 5-17 shows the technical characteristics of this product.

TABLE 5-17: TECHNICAL CHARACTERISTICS OF HYPERION SENSOR[15]

Sensor name Parameter	Hyperion C
Size:	180x40 (lxd)
Weight:	0.5kgs
CAPEX:	-
OPEX:	-
Power Consumption:	0.6 W
Depth:	6000m
Measured Parameters:	1 (chlorophyll-a)
Range Tryptophan:	-
Range Chlorophyll-a:	0-800 µg/l
Range Phenantrene:	-
Accuracy Tryptophan:	-
Accuracy Chlorophyll-a:	0.025 µg/l
Accuracy Phenantrene:	-
Response time:	0.03 - 0.2 sec

The final competing product identified comes from bbe-moldaenke, a German manufacturer of instruments in the environmental technology industry. More specifically, the FluoroProbe is a fluorometer for chlorophyll analysis and algae class determination. Table 5-18 shows the technical characteristics of this product.

TABLE 5-18: TECHNICAL CHARACTERISTICS OF FLUOROPROBE

Sensor name Parameter	FluoroProbe
Size:	450x140 (lxd)
Weight:	6.4kgs

[15] Valeport official website, http://www.valeport.co.uk/Portals/0/Docs/Datasheets/Valeport_Hyperion_C_F_and_R.PDF.

Sensor name Parameter	FluoroProbe
CAPEX:	-
OPEX:	-
Power Consumption:	-
Depth:	1000m
Measured Parameters:	7 (chlorophyll-a, green algae, cyanobacteria, diatoms/brown algae, cryptophytes, yellow substances, depth)
Range Tryptophan:	-
Range Chlorophyll-a:	0-200 µg/l
Range Phenantrene:	-
Accuracy Tryptophan:	-
Accuracy Chlorophyll-a:	0.01 µg/l
Accuracy Phenantrene:	-
Response time:	-

Having analysed the available comparable solutions that are on the market at this moment, one fact is evident. The NeXOS O1 optical sensor system provides a unique combination of measured parameters that cannot be matched by a single product of the competition. In order to have at least the same parameters measured as the O1, it is necessary to use a combination of competitor products. That is a major advantage on its own as it removes the need to install, setup, configure, manage and maintain different devices with different specs and protocols. In this case, the easiest way to achieve the measuring capabilities of the O1 using competition products, without having duplicate sensors, is to combine two instruments namely the C3 Submersive Fluorometer by Turner Designs and the HydroC Subsea Fluorometer. Table 5-19 compares O1 with that combination of instruments.

TABLE 5-19: COMPARISON BETWEEN THE NEXOS O1 AND THE COMPETITION PRODUCTS

Sensor name Parameter	NeXOS O1	HydroC and C3 Combination
Size:	196x36 mm (lxd)	320x175 (lxd)
Weight:	0,5 kgs	6.04 kg
CAPEX:	10000 €	€ 14,000
OPEX:	€500 /year	€ 1,600/year (estimation)
Power Consumption:	2.5 W	5.4 W
Depth:	2000 m	6000m

Sensor name Parameter	NeXOS O1	HydroC and C3 Combination
Measured Parameters:	4 (CDOM/Chloroph-a/PAH/Turbidity)	7 (CDOM, Turbidity, Chlorophyll-a, humic acids, amino acids, BTXE, polycylic aromatic hydrocarbon PAH)
Range Tryptophan:	0-500 ppb	20000 ppb
Range CDOM:	0-200 ppb	0-1250 ppb
Range Phenantrene:	0-50, 0-500 μg/L	0-50, 0-500 μg/L
Accuracy Tryptophan:	<0.2 ppb	3 ppb
Accuracy CDOM:	<0.2 ppb	0.15 ppb
Accuracy Phenantrene:	<0.2, <1 ppb	-
Response time:	<5 sec	-

Clearly, the advantages of NeXOS O1 in this comparison are significant, not only in costs but also in size and measurement accuracy. Assuming that the needs of a given application include measurements of only the four parameters measured by O1 (CDOM, Turbidity, PAH and Chlorophyll-a), then the advantages range from size, to procurement costs, operating costs, power consumption and even measuring accuracy with certain parameters. More specifically, The NeXOS O1 is found to be at least 30% smaller in size, has a 30% lower price than the combination of instruments (assuming only one O1 sensor will ever be manufactured) and consumes less than 50% of the power. Moreover, despite OPEX values not being available for specific competing sensors, industry experts indicate that the annual costs of maintenance and spare parts for O1 are at least 40% lower than those for competing sensors (approx. € 500 compared to € 850) due to the use of smaller equipment. On the other hand, the combination of instruments offers more measuring parameters and higher range/sensitivity figures. Furthermore, another advantage of the combination is that the two instruments can be used separately in case some of the parameters are not necessary to be measured.

5.2.2 *Innovation O2 and the competition*

The second optical innovation within the NeXOS project, referred to as O2, is described as a compact, low-power and multifunctional optical sensor system based on hyperspectral cavity absorption technology, enabling measurement of water constituents such as dissolved organic matter, suspended matter, and phytoplankton. Table 5-20 contains the main technical properties of the NeXOS O2 sensor system.

Table 5-20: Technical characteristics of NeXOS O2

Sensor name Parameter	NeXOS O2
Size:	45*6.8/13.0 (lxd)
Weight:	3 kgs
CAPEX:	€ 25,000
OPEX:	€ 1,000 / year

Sensor name Parameter	NeXOS O2
Power Consumption:	5 W
Depth:	300 m
Measured Parameters:	1 (Absorption)
Range Absorption:	0.01-10 m-1
Accuracy Absorption:	0,05
Maintenance interval:	12 months
Phytoplankton groups:	7

As far as the competition sensors are concerned, the market research showed that the NeXOS O2 is indeed the only instrument with these capabilities at the moment. After exhaustive interviews with industry experts and leading manufacturers, it was made evident to us that there is only one product capable of being considered comparable, although with a different measuring concept, as will be explained further. This competing product is the ICAM by Turner Designs.

Turner designs, an American instrument manufacturer, produces ICAM, an "in-situ Integrating Cavity Absorption Meter, configured with nine wavelengths ranging from UV (365nm) to Red (676nm) enabling absorption measurements over a wide spectrum". The most important difference, compared to O2, is that the ICAM measures other parameters and uses these readings to calculate absorption via algorithms. It is necessary to mention at this point that such algorithms are created based on a number of substantial assumptions that affect the accuracy of the result. On the other hand, NeXOS O2 is the only instrument at this time that directly measures absorption. Table 5-21 shows how the NeXOS O2 sensor system compares against the competing product.

TABLE 5-21: COMPARISON BETWEEN THE NEXOS O2 AND THE COMPETITION PRODUCTS

Sensor name Parameter	NeXOS O2	ICAM
Size:	45*68/130 mm (lxd)	787x178 (lxd)
Weight:	3 kgs	15kgs
CAPEX:	€ 25000	€ 31.000
OPEX:	€ 1000	€ 950
Power Consumption:	5 W	25 W
Depth:	300 m	200m
Measured Parameters:	1 (Absorption)	1 (cavity absorption)
Range Absorption:	0.01-10 m-1	0.001-15 m-1
Accuracy Absorption:	0,05	-
Maintenance Interval:	12 months	-

Phytoplankton groups:	7	-

Immediately, the main advantages of O2 are visible, namely size, weight and power consumption. In fact, O2 occupies a tenth of the volume compared to ICAM and weights a fifth of its weight.. NeXOS O2 is also significantly cheaper to buy, while having almost equal operational expenditure needs. Finally, O2 has a stunning 5 times smaller power consumption in comparison to ICAM. However, the fact that O2 actually measures absorption without the need of intermediary algorithms and assumptions, is the major advantage significantly increasing the accuracy and reliability of measurements. This consists a major breakthrough for this type of environmental monitoring.

5.2.3 *Innovation O3 and the competition*

The third optical innovation within the NeXOS project, namely O3, is described as a compact, low-power, multifunctional carbon sensor system. Such sensor arrays are used to quantify the marine carbonate system by combination of a high precision sensor for pH and AT together with a membrane based pCO2 sensor. The O3 system includes high precision spectrophotometric pH and carbonate ion sensor with a membrane based pCO2 sensor. Furthermore, the O3 innovation comes in two types of array namely Cbon2 (measuring pH and pCO2) and Cbon3 (measuring pH, pCO2 and AT). Cbon2 array has two different layouts, one for ferrybox deployment and one for surface vessel deployment. Table 5-22 shows the technical characteristics of the three NeXOS O3 alternatives.

TABLE 5-22: TECHNICAL CHARACTERISTICS OF THE DIFFERENT NEXOS O3 TYPES

Sensor name Parameter	O3 Cbon2-fb	O3 Cbon2-sv	O3 Cbon3-fb
Size:	40x50x20 cm	30x20x14 in	40x50x20 cm
Weight:	-	-	-
CAPEX:	€ 20,000	€ 35,000	€ 25,000
OPEX:	€ 2,000 / year	€ 2,000 / year	€ 2,000 / year
Power Consumption:	25 W	20 W	75 W
Depth:	-	-	-
Measured Parameters:	2 (pH, PCO2)	2 (pH, PCO2)	3 (pH, PCO2, TA)
Range pH:	7.8 - 8.4	7.8 - 8.4	7.8 - 8.4
Range pCO2:	250 - 700 µatm	250 - 700 µatm	250 - 700 µatm
Range AT:	-	-	2000 - 2400 µmol/kg
Accuracy pH:	0.005	0.005	0.005 - 0.003
Accuracy pCO2:	2%	3%	-
Accuracy AT:	-	-	1%

As with the previous NeXOS innovations, there is not a single product at this moment on the market that can directly compete with the O3 system. Therefore, competing sensors that can measure similar parameters have been taken into account. These are:

- The SAMI-CO2 and SAMI-pH by Sunburst sensors;
- The C-sense pCO2 by Turner designs; and
- The HydroC CO2 by Contros (Kongsberg).

Sunburst sensors, an American designer and manufacturer specialized in carbon dioxide and pH instruments, provides a submersible autonomous moored instrument (SAMI) in two forms. One for measuring pCO2 and one for pH measurements. These instruments can run autonomously up to one year (with hourly measurements and supplemental battery pack) and can support up to 3 external instruments, for additional measurements. Table 5-23 shows the technical characteristics of these products.

TABLE 5-23: TECHNICAL CHARACTERISTICS OF THE SAMI-CO2 AND SAMI-PH

Sensor name Parameter	SAMI-CO2	SAMI-pH
Size:	550x152 mm (lxd)	550x152 mm (lxd)
Weight:	7.6kgs	7.6kgs
CAPEX:	-	-
OPEX:	-	-
Power Consumption:	-	-
Depth:	600m	600m
Measured Parameters:	1 (pCO2 – up to 3 external instruments possible for PAR, dissolved oxygen, chlorophyll fluorometer or CTD possible)	1 (pH – up to 3 external instruments possible for PAR, dissolved oxygen, chlorophyll fluorometer or CTD possible)
Range pH:	-	7-9 pH
Range pCO2:	200-600 µatm	-
Range AT:	-	-
Accuracy pH:	-	±0.003
Accuracy pCO2:	±3 µatm	-
Accuracy AT:	-	-

The next competing product comes from Turner Designs, a manufacturer that offers competing product to other NeXOS innovations as well, produces the C-sense pCO2 sensor. According to the manufacturer, the main advantage of this sensor is the compact size and very low price, compared to similar products. Table 5-24 shows the main technical characteristics of this product.

TABLE 5-24: TECHNICAL CHARACTERISTICS OF THE C-SENSE PCO2

Sensor name Parameter	C-sense pCO2
Size:	230x51 (lxd)

Sensor name Parameter	C-sense pCO2
Weight:	0.5kgs
CAPEX:	7.020
OPEX:	-
Power Consumption:	0.48 W
Depth:	b600m
Measured Parameters:	1 (pCO2)
Range pH:	-
Range pCO2:	0-1000/2000/4000/10000 ppm
Range AT:	-
Accuracy pH:	-
Accuracy pCO2:	3% of full scale
Accuracy AT:	-

The final product in this comparison comes from Contros (now part of Kongsberg), in the form of an underwater carbon dioxide sensor for in-situ and online measurements of CO2. The HydroC Co2 sensor can be used in various platforms including moving installations, ROVs, AUVs, buoys and moorings. Table 5-25 shows the main technical characteristics of this particular competing solution.

TABLE 5-25: TECHNICAL CHARACTERISTICS OF THE HYDROC CO2

Sensor name Parameter	HydroC CO2
Size:	380x89 (lxd)
Weight:	4.5kgs
CAPEX:	-
OPEX:	-
Power Consumption:	12 W
Depth:	2000-6000m
Measured Parameters:	1 (pCO2)
Range pH:	-
Range pCO2:	0-1000/2000/4000/10000 ppm

Range AT:	-
Accuracy pH:	-
Accuracy pCO2:	1%
Accuracy AT:	-

Unfortunately, as the available data for the competition sensors of O3 regarding their technical characteristics, costs and compatibility between them are rather limited, a comprehensive side by side comparison is not possible. Furthermore, no other commercially available solutions have been identified that can match the functionalities of O3 Cbon3-fb i.e. *in-situ* measurements. As such, for comparison purposes, the remaining versions of O3 will be compared against the combination of SAMI-pH and SAMI-CO2. Table 5-26 shows that comparison. Here it can be seen that the O3 sensors are considerably less voluminous and can be thus mounted more easily to platforms.

Table 5-26: Comparison between the NeXOS O3 and the competition products

Sensor name Parameter	O3 Cbon2-fb	O3 Cbon2-sv	SAMI CO2 + SAMI pH
Size:	40x50x20 cm	30x20x14 in	550x304 mm (lxd)
Weight:	-	-	15.2kgs
CAPEX:	€ 20,000	€ 35,000	-
OPEX:	€ 2,000 / year	€ 2,000 / year	-
Power Consumption:	25 W	20 W	-
Depth:	-	-	600m
Measured Parameters:	2 (pH, pCO2)	2 (pH, pCO2)	2 (pH, pCO2)
Range pH:	7.8 - 8.4	7.8 - 8.4	7-9
Range pCO2:	250 - 700 µatm	250 - 700 µatm	200-600 µatm
Range AT:	-	-	-
Accuracy pH:	±0.005	±0.005	±0.003
Accuracy pCO2:	2%	3%	±3 µatm

Accuracy AT:	-	-	-

6. ADDED VALUE IN VIEW OF APPLICATIONS

In this chapter, the advantages of the NeXOS innovations, in comparison with competing off-the-shelf sensors presented in the previous chapter, will be translated into actual operational benefits. This is an important step towards having a better understanding of how these advantages create added value, when they are applied in the field. In order to arrive to the added value produced by a certain advantage, a logical path of causal relationships has been established. These relationships link a certain advantage to the added value that it can potentially produce, through a series of logical steps that describe the operational variations caused by said advantage. The competition comparison that has been presented in the previous chapter, revealed nine relevant characteristics that can distinguish one instrument from another and can produce added value. These are:

- Physical properties – Dimensions and Weight;
- Power consumption;
- Multi-functionality (number of measured parameters);
- Capital and operational costs (CAPEX and OPEX);
- Operating Depth (and temperature);
- Quality of measurements (Range and Accuracy);
- Maintenance requirements (Antifouling technology);
- Interface interoperability (Plug-and-Play);
- Data interoperability and communication load.

In the following paragraphs, each of these nine characteristics is analysed in respect to how it brings added value and what exactly that added value is. The causal diagrams that are used to depict that have three main components namely the characteristic/advantage producing added value (dark blue colour), the changes it brings to the monitoring processes (in light blue) and the actual added value produced because of these (in green).

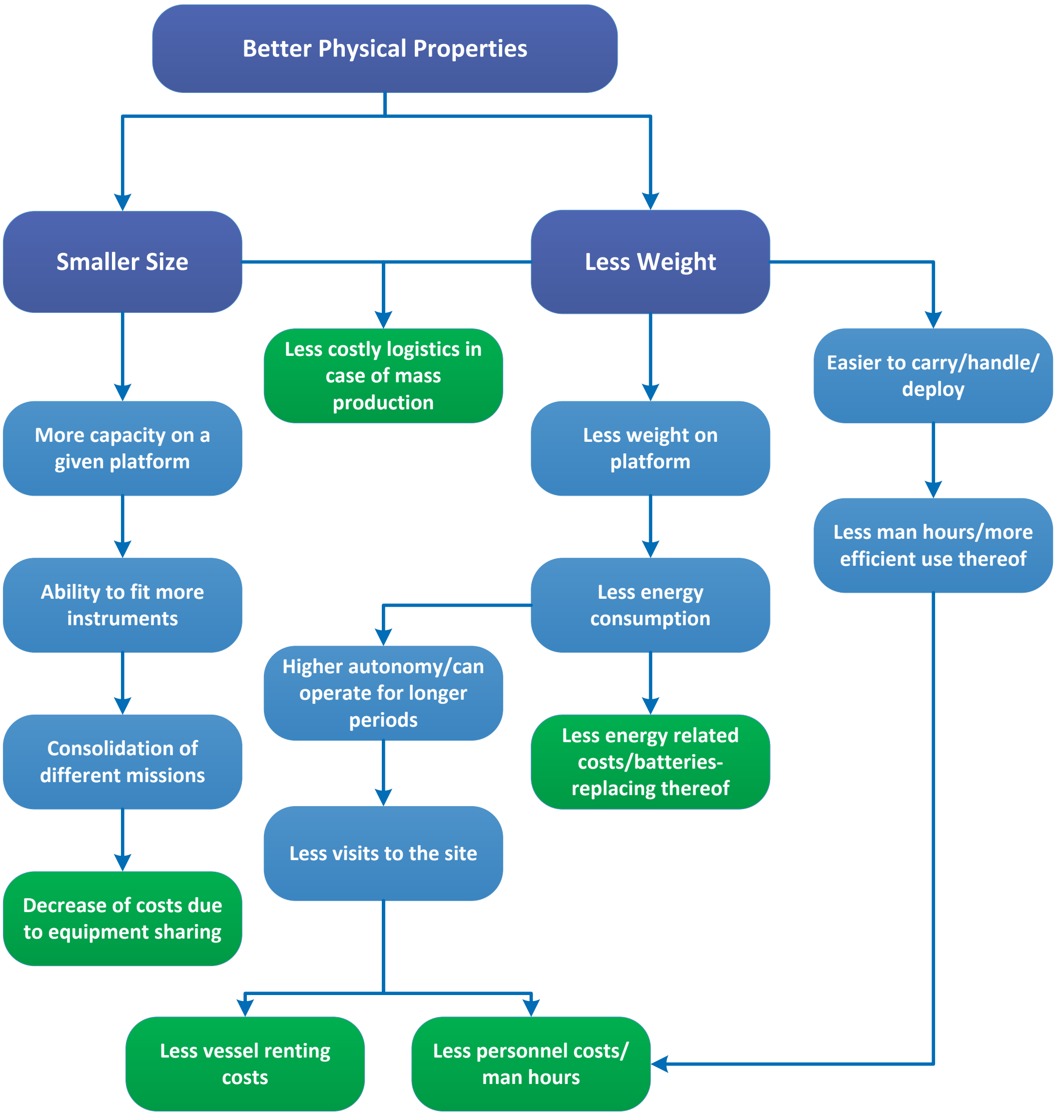
6.1 Assessment of the benefits of the NeXOS innovations

6.1.1 *Physical Properties – Dimensions and Weight*

Going through all the available solutions in environmental monitoring, one can find a great variety of instruments either made with a very specific function in mind, or targeting a wider range of applications. However, the physical properties, such as size and weight, is a characteristic they all share, a rather significant one. Although, in general, all relevant instruments tend to have small dimensions, the nature of environmental monitoring applications makes even the smallest variation matter. This is due to the fact that instruments need to be integrated on a certain platform (buoy, glider, ROVs, AUVs etc.) that provides from just transportation to power source, data logging, data transmission, communications and other functions. Such platforms have a limited amount of space available to house instruments and usually have limited power supply. Therefore, instruments should in principle be as small and as light as possible in order to work in harmony with the platforms.

As seen in Figure 6.1, physical properties are split in two categories: size and weight. Immediately, one can spot at this level the first form of added value that is produced as a result, that is cheaper logistics. Although the end-user hardly ever comes in touch with that part of the value chain, it is very important once we look at a given instrument as a product and not just as a scientific measuring tool. Smaller-sized sensors can be packaged in smaller boxes, leading to more efficient consolidation in shipments, hence lower transport costs per instrument. As production numbers become larger, economies of scale kick in, making such cost savings very significant. The same holds for weight, although here there is even more to be gained. Firstly due to fuel savings from transporting less weight and secondly, making the instrument easier to transport with modes for which weight is crucial e.g. air transport.

FIGURE 6.1: THE ADDED VALUE OF BETTER PHYSICAL PROPERTIES



Diving in further detail, size reduction leads to different forms of added value than reduction in weight does. More specifically, smaller size in instruments is directly related to the platforms that will be housing them during missions. Given a certain platform, a reduction in size of instruments leads to more space being available on the platform, opening up the ability and/or possibility to fit more instruments on said platform. As a result, that extra capacity can be used for the purposes of other missions in the same waters, leading to cost reduction from sharing the platform and the related expenditure.

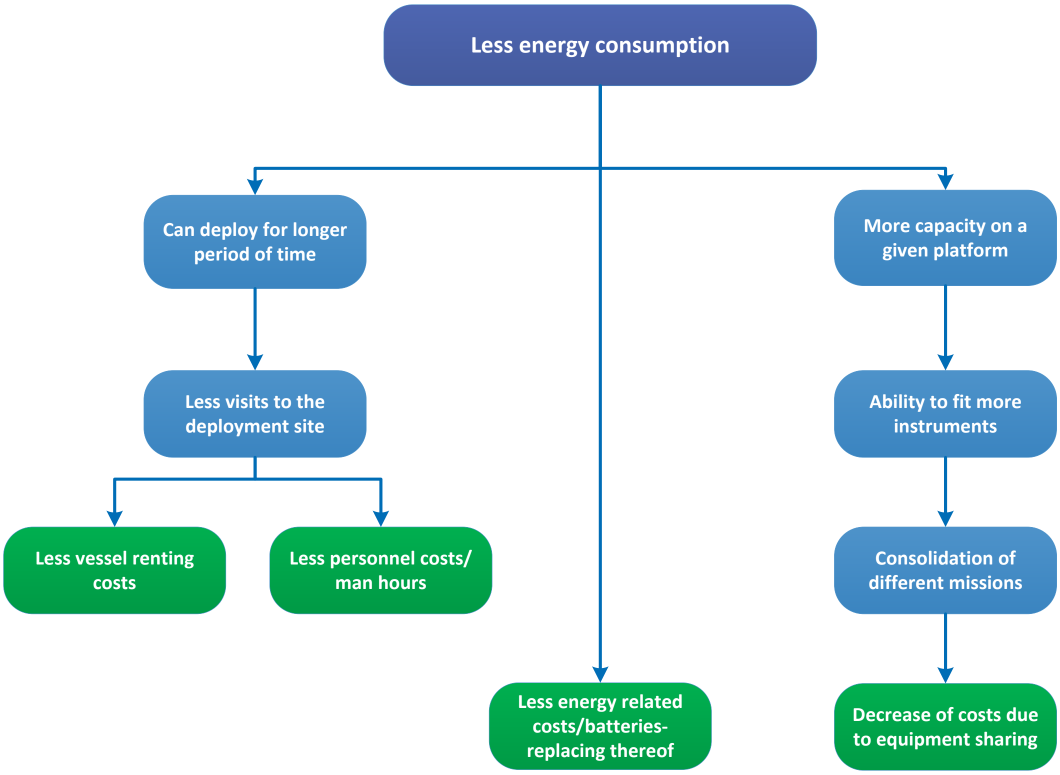
On the other hand, reduction in weight brings more multifarious benefits. Firstly, the obvious benefit has to do with the ease of handling. Lighter equipment is easier to carry around, deploy and operate. Less manual labour-intensive procedures lead to fewer and more efficiently used man-hours and therefore the added value of less operating costs in the long-term. Secondly, the weight of instruments affects directly the platform that is housing them. A lighter monitoring system is moves easier in water, thus consumes less energy to achieve the same result. Instantly, the added value of less energy consumption is produced that, in sequence, leads to lower related costs be it from the lower consumption itself and the potential costs of replacing/purchasing batteries. Furthermore, assuming the rest of the monitoring system remains unchanged, lower power consumption from the instruments means higher autonomy. As such, the same monitoring system can now be in operation for longer periods of time, resulting in less visits to the deployment site and, therefore, the twofold added value of less vessel renting and personnel costs. In large scale monitoring operations with long duration and in areas with restricted accessibility, these costs can easily add up to a significant amount.

To conclude, improved physical properties of a monitoring instrument has the potential to create added value in six different ways and in relation to logistics, deployment and operational costs.

6.1.2 *Power consumption*

When it comes to ocean monitoring and hydrography applications that involve the use of sensors, energy consumption is always a main concern. As such operations tend to take place in remote environments, energy supply can be anywhere from limited to not available whatsoever. Energy needs are usually fulfilled through the use of batteries, either internally in the instruments or externally through the platform. Therefore, availability of necessary energy sources is paramount for the uninterrupted continuation of acquiring the desired measurements. With that in mind, betterment in energy consumption has a threefold added value, as depicted in Figure 6.2. The first direct result from consuming less energy is the reduced need for batteries therefore lower related costs.

FIGURE 6.2: THE ADDED VALUE OF LESS ENERGY CONSUMPTION



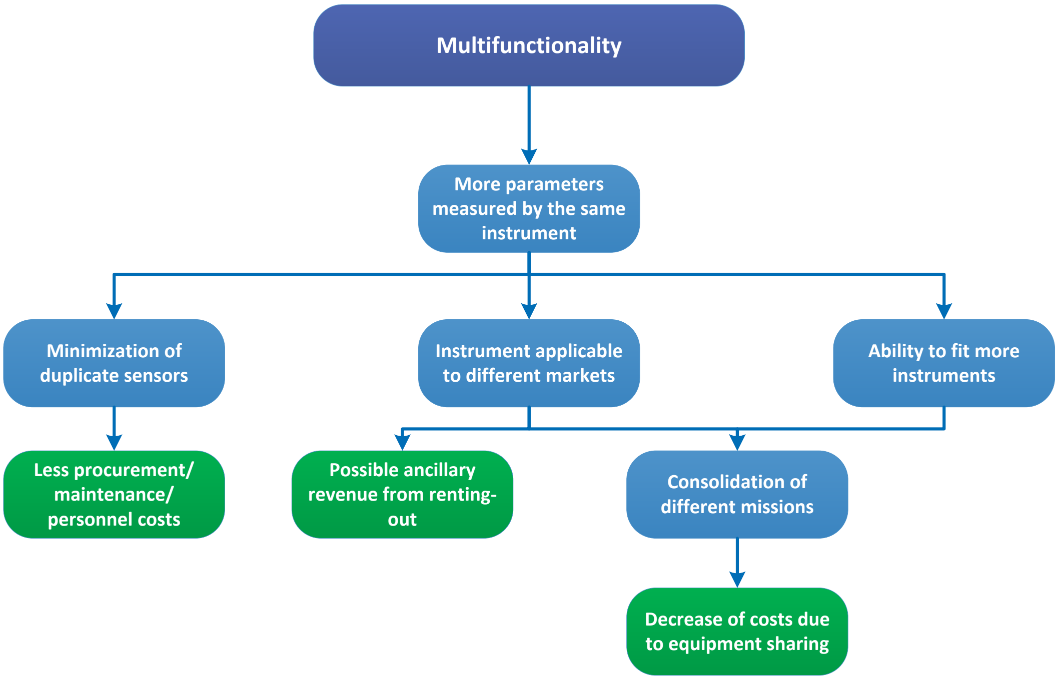
In addition to that, assuming that the remaining components remain the same, the monitoring system as a whole can be deployed for longer periods of time, as the energy consumption per measurement is reduced. As industry experts have pointed out, this is of great significance. Longer deployments mean that the need to visit the deployment site is reduced. The costs associated with site visitations can be very high, as usually it involves renting a properly equipped scientific vessel, with its crew and any other specialized personnel necessary. It is easy to understand that none of these components comes cheap, bringing us to the added value of less costs from vessel renting and labour hours.

Finally, as described previously, power consumption is directly associated with the platform housing the instrument. Assuming that a given platform has a finite source of energy, the reduction in the energy consumption of instruments frees up capacity on that platform, energy-wise. That, in turn, opens up the possibility to fit more instruments on the same platform, hence consolidate different mission in the same waters. The added value here comes from sharing the equipment (platform, vessels etc.) and therefore the costs.

6.1.3 *Multi-functionality*

In the modern market of environmental monitoring instruments, almost all available products have some level of multi-functionality that is being able to perform more than one type of measurements at the same time. That is also a major characteristic of the NeXOS innovations, as it has been shown in previous chapter. The increase in number of measured parameters from the same instrument can result in a variety of benefits, related mostly to the platform. To be more precise, as a single instrument becomes available to measure more parameters, the need for other single-parameter instruments is reduced. Consequently, the place that these used to occupy on a platform becomes available for other instruments. As described also in previous paragraphs, that opens up the possibility to consolidate different missions and profit from sharing the cost burden.

FIGURE 6.3: ADDED VALUE FROM MULTI-FUNCTIONALITY



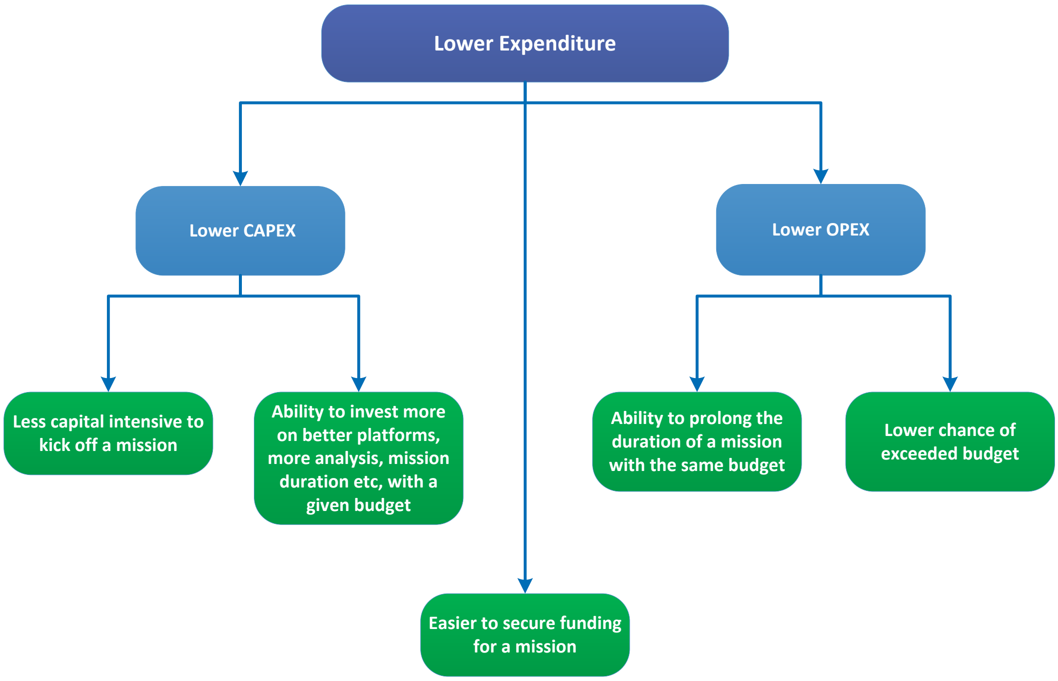
Furthermore, as industry experts have pointed out, it can often be the case that the combination of different instruments for the same mission results in having duplicate sensors. The same parameter can then be measured by more than one available instrument which means that a portion of the equipment is not used as efficiently as possible and unnecessary costs occur. As instruments become more multifunctional, the risk of carrying more sensors than needed is reduced and, therefore, equipment procurement, maintenance and specialised personnel costs are reduced.

Additionally, from an economic perspective, instruments that perform a variety of functions are more likely to be applicable for different markets with varying needs. As an equipment manufacturer, this can prove to be a very important benefit as the same product can be marketed to a wider audience and result in better sales performance. Additionally, instrument owners/users can also benefit as their equipment becomes relevant to other users as well, opening up the possibility for renting out said equipment and acquire the ancillary revenue that comes with it. Figure 6.3 shows how multi-functionality can lead to the aforementioned added value elements.

6.1.4 *Capital and operational costs*

As with every operation, scientific or otherwise, a key component from the very beginning is the available budget, in other words the financial aspect. Securing the necessary funding is a time consuming process and can be the decisive factor behind a project being realised or not. In the previous chapter, where a variety of instruments was presented, there is one characteristic that can be said is common amongst them: the high price tag. Of course, this is expected for scientific instruments made with the highest precision possible in mind and with the use of expensive materials, suitable for remote, underwater environments. Nevertheless, lowering the expenditure is always desirable, both in capital (CAPEX) and operational costs (OPEX), as shown in Figure 6.4.

FIGURE 6.4: THE ADDED VALUE OF LOWER EXPENDITURE



From a general point of view, lower expenditure introduces a direct added value that of greater ease of securing funds necessary for a mission. It goes without saying that the less amount of money needed, the more probable is to raise said amount. Assuming that the available funds are a fixed amount, this would make funding sources available towards purposes that could not be funded previously, widening the scope and market of environmental monitoring.

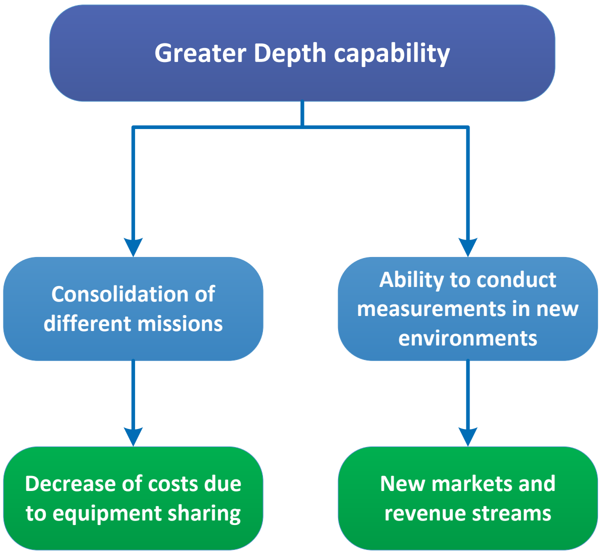
Going into more detail, capital expenditure differs from operating expenditure in regards to the added value they bring. The former results in a given monitoring process being less capital intensive to begin with, which either can be of use in justifying it as a business case or, use the extra capital that is now made available to expand the process. That could mean platform upgrades, better or more analysis and tools, grater duration etc.

In the latter, users can enjoy the twofold benefits from lower operating expenditure during and after the actual deployment of the instrument. Enduring lower operating costs introduces two potential benefits. At first, assuming that the total budget remains the same, it allows the user to prolong the duration of a certain mission, for the same amount of total cost. Secondly, the threat of exceeding the predefined budget is minimised, as a financial buffer is created that can absorb any potential unforeseen costs related to operations. As an extra added value, it can be mentioned at this point that as relevant projects become more financially well-defined and kept within budget, funding them becomes more attractive for the capital holder and, in the long term, this will lead to more funding becoming available towards such activities.

6.1.5 *Operational depth (and temperature)*

As it is expected, depth rating is one of the most important features of any water monitoring equipment. Applications vary greatly in respect to the depth where they need to take place, in order to find the necessary environmental conditions, reach the natural habitat of certain species etc. Also, different markets and industries have different needs in that area and, on top of that, different areas of the world have waters with varying depths, making this an important distinction between available instruments.

FIGURE 6.5: THE ADDED VALUE OF GREATER DEPTH CAPABILITY

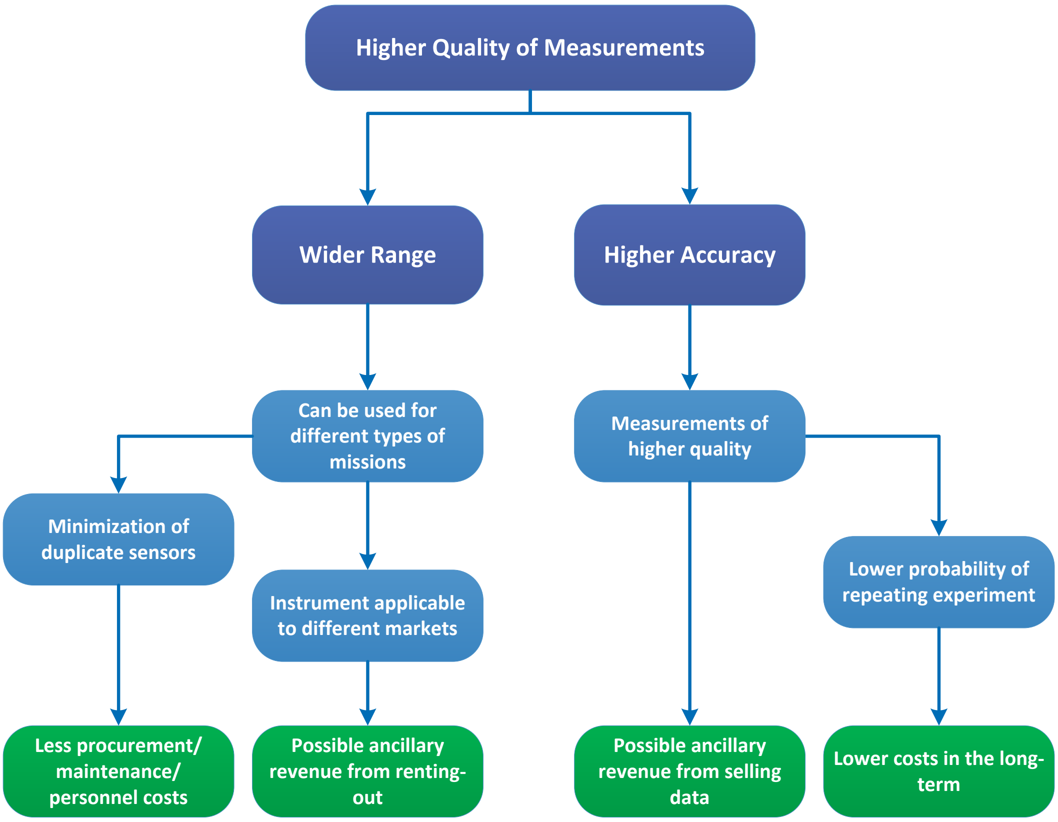


In Figure 6.5, it can be seen how greater depth capabilities of instruments lead to added value. On the one side, as instruments become able to reach and operate in greater depths, the different missions (and their varying objectives) that they can serve consolidate. As such, more markets can be accommodated with the same sensor, resulting in the ability to consolidate different missions and profit from sharing the costs, as it has also been seen with previous cases. On the other hand, the ability to conduct measurements in greater depths allows access to previously unreachable environments and uncharted territories. As a consequence, new markets and needs are created that will eventually lead to new revenue streams for those involved in the whole value chain.

6.1.6 *Quality of Measurements (Range and Accuracy)*

Another characteristic that distinguishes environmental monitoring instruments is the quality of the measurements it can produce. Quality, as a concept in this area, can be summarised with its two main components namely range and accuracy. Figure 6.6 shows how these two quality components lead to added value.

FIGURE 6.6: THE ADDED VALUE OF HIGHER QUALITY OF MEASUREMENTS



A wider range of possible measurements by the same type of instrument can potentially result in both lower costs and increased revenue. In more detail, such an instrument becomes applicable for use in more types of missions that need to measure a certain parameter in different spectra. By doing so, on one hand, having duplicate sensors on the same platform becomes less of a probability, leading to cost savings. On the other hand, the same instrument becomes able to meet the demands for measurements that other additional markets have. Therefore, the target audience is enlarged bringing potential for more revenue as an added value.

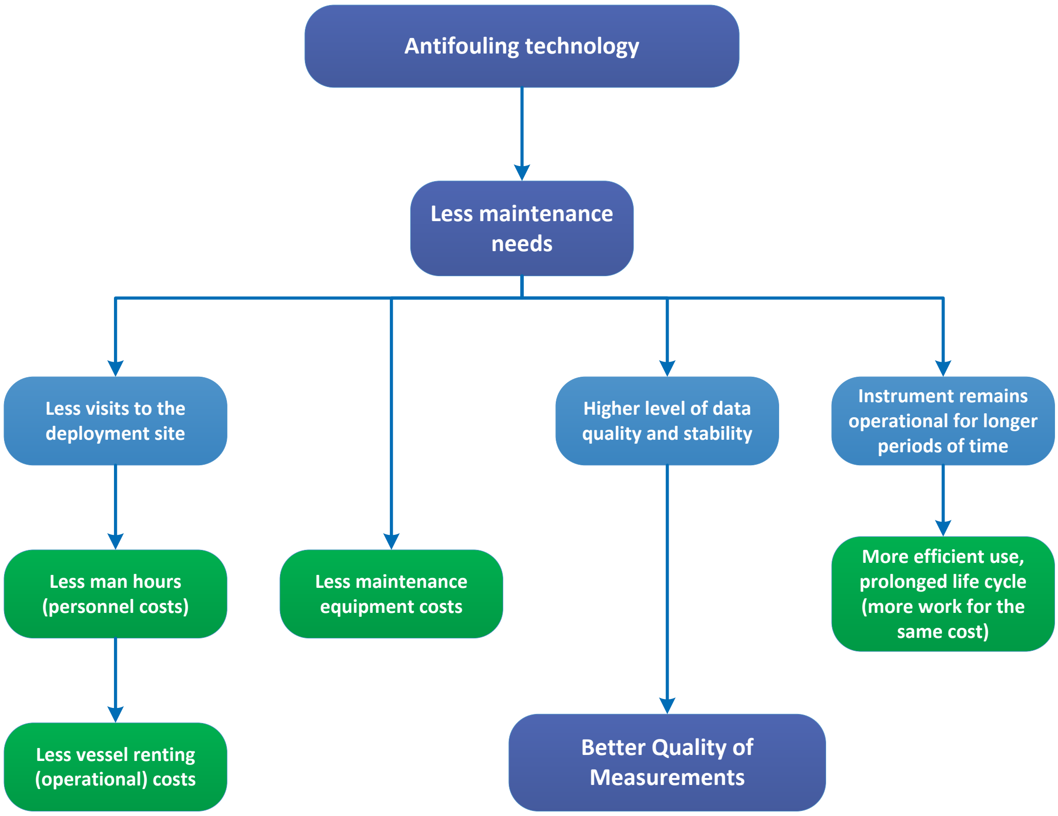
Regarding the other component of measurements quality, higher accuracy can have as a result also benefits in the form of lower costs and higher revenue, only through a different path. At first, instruments that take measurements of higher accuracy can help produce analysis and results of higher quality. In doing so, the measurements data of such an instrument become more desirable, hence allowing the owner/user of the instrument to profit from ancillary revenue coming from selling the produced data to third parties. Furthermore, in a more scientific perspective, higher accuracy measurements leave less room for errors and deviation from the actual values of the measured parameter. Accordingly, the probability of having to repeat a mission or an experiment is lowered. As in such instances a large part, if not in full, of the process has to be repeated, in order to maintain scientific correctness and continuity, the involved costs can be at best significant. Therefore, higher accuracy leads directly to cost savings due to lower error margins and less repetition.

6.1.7 *Maintenance requirements (Antifouling technology)*

In the context of scientific instruments for underwater measurements, antifouling corresponds to the prevention of the growth of organisms on surfaces under water. The importance of fouling prevention varies by type of sensor or instrument in general. For example, effective antifouling solutions are crucial to the operation of optical sensor, as such growths can prevent light from reaching the sensor, rendering it ineffective. On the other hand, acoustic sensors are not affected much, as sound waves can propagate through such organism growths. Nevertheless, for the purposes of this analysis, antifouling is tackled from a higher level, in order to reveal the potential added value that can be produced, in all possible cases.

As illustrated in Figure 6.7, advancements in antifouling technology are directly related to less maintenance needs, arriving thus directly to a reduction in all maintenance related costs. These can include various maintenance equipment or spare parts as well as other additional costs such as potential vessel renting and operating costs (as site visitation is necessary to solve fouling problems) and, of course, the costs of the specialised personnel that will handle the issue at hand.

FIGURE 6.7: ADDED VALUE OF LESS MAINTENANCE REQUIREMENTS (ANTIFOULING)



Besides these benefits, more effective antifouling technology results in measurements of higher stability and quality. This case becomes more evident where fouling becomes a great nuisance, as in the case of optical sensors. Organism growths take some time to develop on the sensor surface and, as a result, the created hindrance develops gradually and over time. Therefore, it could be the case that, until the fouling problem is identified, measurements have already been affected. As such, better antifouling protections leads to better measurements quality that, as seen in paragraph 6.1.6, provides added value in four different ways, allowing for lower costs and higher revenue.

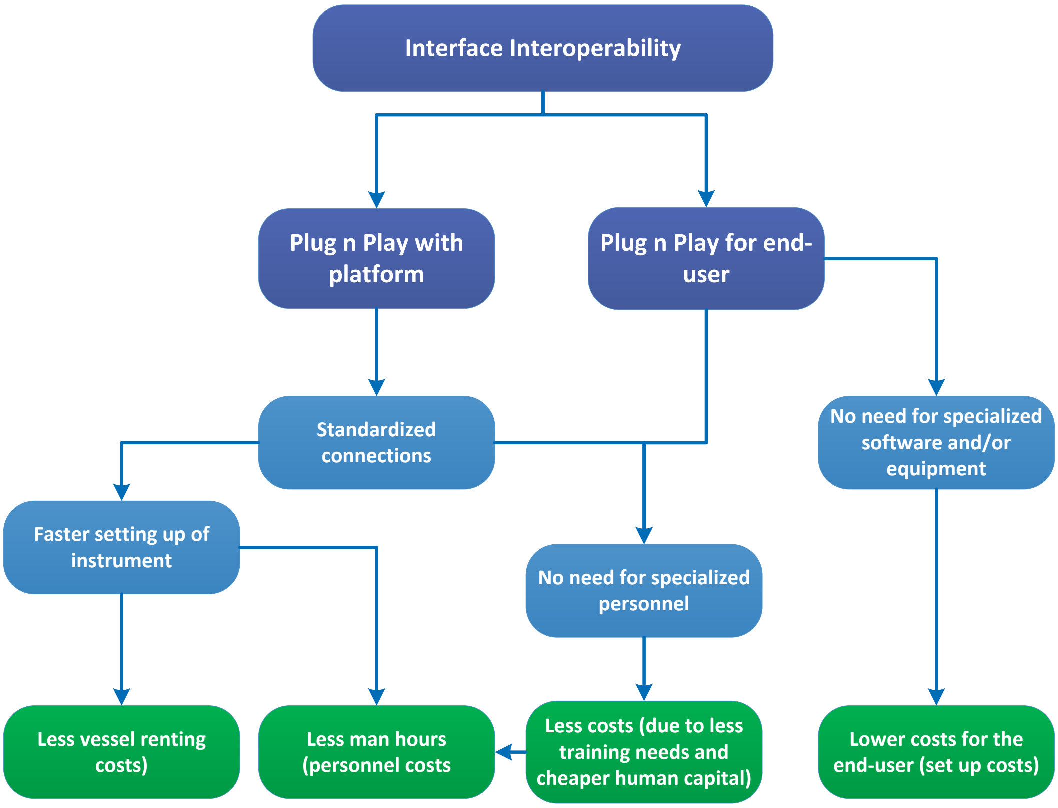
Moreover, from a purely operational perspective, the minimization of problems caused by fouling amounts to the instrument being operational for longer periods of time, uninterrupted. In that sense, the instrument is used with higher efficiency and is able to produce more work (measurements) for the same cost. In the long run, the benefits from this form of added value can become quite significant.

6.1.8 *Interface interoperability (Plug-and-Play)*

It is generally accepted in the scientific community that the communications with the instrument is a critical issue in a network of sensors in the marine environment[16]. As such, the capacity of an instrument for interoperability with various systems and platforms is one of the most important characteristics thereof. As indicated in Figure 6.8, benefits can be recognised in two areas, interoperability with the platform and interoperability with the end-user.

[16] D. M. Toma, J. del Rio, S. Jirka, E. Delory and J. Pearlman, "Smart electronic interface for Web Enabled Ocean Sensor Systems," Sensor Systems for a Changing Ocean (SSCO), 2014 IEEE, Brest, 2014, pp. 1-4. doi: 10.1109/SSCO.2014.7000375.

FIGURE 6.8: THE ADDED VALUE OF INTERFACE INTEROPERABILITY



In terms of interoperability with the platform, instruments that offer plug and play capability through standardised connections can help reduce the preparation effort and time significantly. Platform manufacturing industry experts[17] have strongly pointed out the importance of this item, stating that incompatibility issues between sensors and platform can be responsible for up to 80% of the total preparation time needed before deployment. In this regard, it can be concluded that plug and play capability results in significantly faster equipment setting-up and, therefore, cost savings in terms of personnel costs as well as vessel renting costs, in case the fitting of the instruments needs to be performed on-site.

From the end-user perspective, an instrument that can operate in plug and play mode minimises the requirements for configuration of the instrument and/or or user interference in resolving any potential conflicts. Consequently, the user endures less cost as there is no need for specialized software or equipment to facilitate the process. Finally, a common area of added value that is potentially brought in both platform and end-user perspective, is the reduction in need for specialized personnel that handles the platform-instrument-end user set-up for the instrument. Cost saving there potentially propagate towards the direction of personnel training costs and all aspects of human capital costs.

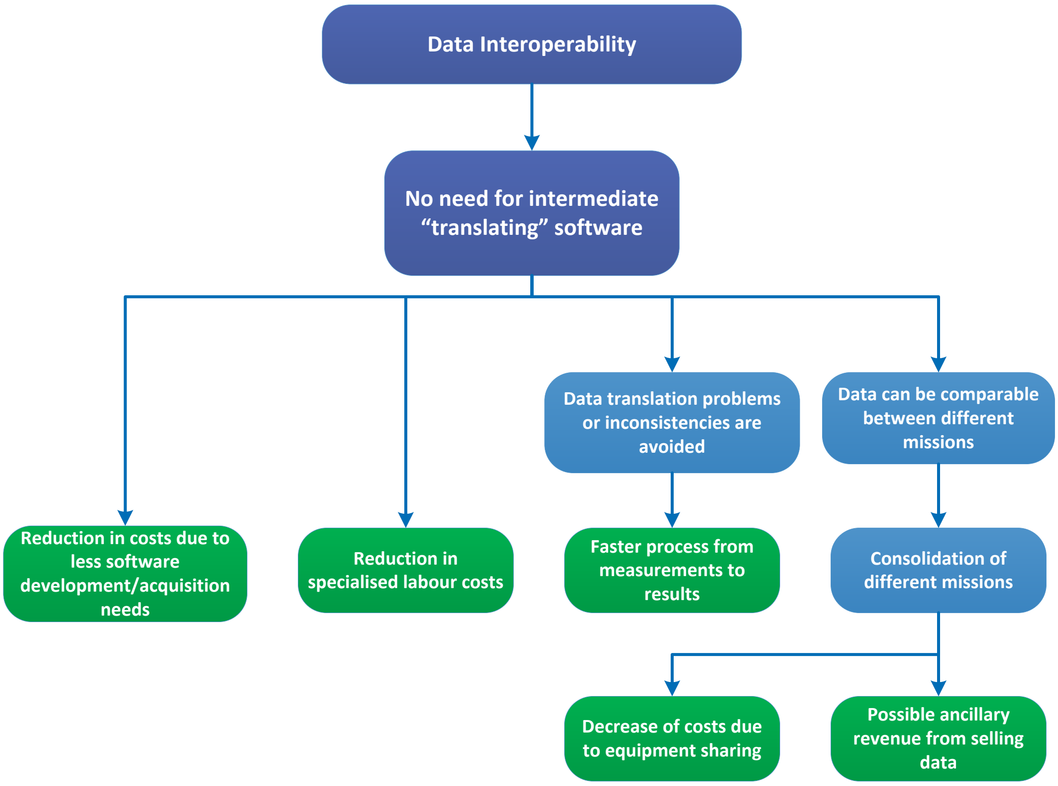
6.1.9 *Data interoperability and communication load*

In the sensor and scientific instrument area, data interoperability signifies the ability for the measurements data produced to be usable between users and systems. For the time being, a big portion of the sensor measurements and the relevant data produced is of limited value as the usage of it is hindered by proprietary systems and by user or device-specific applications[18]. Consequently this gap creates an opportunity for horizontal use of the data produced, aggregating even available resources and achieving economies of scale. The focus can then be shifted more towards the user needs, irrespective of the context of the mission.

[17] Informal discussion with SAAB Seaeye representative at OI2016 in London.
[18] Milan Milenkovic, Towards a Case for Interoperable Sensor Data and Meta-data Formats, Naming and Taxonomy/Ontology, Intel Corporation, Internet of Things Group, https://www.w3.org/2014/02/wot/papers/milenkovic.pdf.

This lack of need to “translate” the data between different applications and systems adds a great deal of value, as shown in Figure 6.9, bypassing the intermediate software is, in essence, what creates the added value.

FIGURE 6.9: THE ADDED VALUE OF DATA INTEROPERABILITY



More specifically, a direct benefit from removing the intermediate step of data translation is, in itself, the cost savings achieved from not developing and acquiring such specialised software anymore. In addition, particularly because these software applications are sensor and user specific, specialised personnel are often necessary to operate them. In the case of instruments with advanced data interoperability, these costs are also avoided.

Next to that, as users become able to use data horizontally, the possibility to cross-reference or co-analyse data from different mission opens up. This then leads to the possibility of consolidating different mission which, as seen previously, adds value in both lowering the total costs and by bringing in new revenue streams.

The benefits from data interoperability would be limited to this point, if one assumes that these “translating” intermediate software are always working as intended. However this is not always the case. Not only in the sensor environment, but generally in the technical world, whenever there is a need to couple different systems that were not designed to work as one, significant problems occur. Therefore, removing this intermediate step allows all the involved parties to eliminate all these hindrances that can be very costly, if one takes into consideration the time spend on such issues, man-hours and even the risk of contaminating the data and rendering it useless.

6.1.10 *Summary of NeXOS benefits*

The following table presents a summary of the types of expected benefits by each type of improvement targeted by the NEXOS sensor and transversal innovations.

TABLE 6-1: OVERVIEW OF ADDED VALUE FROM NEXOS INNOVATIONS[19]

NeXOS improvements	Added value (Benefit or cost saving types)				
Physical properties	Equipment and platform cost	Maintenance costs	Personnel costs	Energy savings	Improved logistics
Power consumption	Battery costs	Maintenance costs	Personnel costs	Equipment costs	
Multifunctionality	Procurement costs	Maintenance costs	Personnel costs	Sensor reuse potential	
Capital & operational costs	Procurement costs	Operational costs	Improved project setup	Better project financing	
Operational depth	Equipment costs	New markets			
Quality of measurements	Reduced uncertainty	Maintenance costs	Personnel costs	Sensor reuse potential	Data selling
Maintenance (antifouling)	Maintenance costs	Personnel costs	Operational costs	Improved lifecycle	Quality of measurements
Interface interoperability	Personnel costs	Set up costs	Operational costs		
Data interoperability	Data selling	Equipment costs	Personnel costs	Improved lifecycle	Set up costs

6.2 Quantification of NeXOS innovation benefits and cost savings

In this section we attempt to provide a quantitative basis to the different types of expected benefits of the NeXOS innovations. These estimations are based on factual data regarding the costs of underwater environmental monitoring. The aim is here to provide an understanding of the scale of the potential benefits for each type of monitoring improvement pursued by the NEXOS innovations where possible. Therefore, we expand on the potential benefits of reduced power consumption, capital and operational costs as well as the benefits of improved interfaces, data interoperability, quality of measurements and maintenance (antifouling).

This section does not attempt to quantify the benefits of **improved physical properties** and that of the **sensor multi-functionality** because the impacts of these improvements are complex and thus difficult to quantify with certainty. Especially concerning multi-functionality, the improved sensor characteristics are likely to deal a radical impact on the design of monitoring activities since the whole platform-sensor compilation for performing a measurement will likely be altered by the potential of measuring multiple environmental parameters with one sensor.

6.2.1 *Estimation of underwater monitoring market size*

Quantified data on the size of the underwater monitoring market is scarce, and most recent puclications only point to its significance in qualitative terms. The most specific research, by MRAG, dates back to 2009. According to their investigation, 5 EU Member States leading in marine research (The United Kingdom, France, the Netherlands, Sweden and Sweden) together spent €289 million in obtaining observation data. The majority of these funds (64%) had been devoted in data collection, equalling € 184 million. This covered roughly 90% of the data used with the rest coming from different sources, bringing the total cost of data for these countries to roughly €200 million. According to the

[19] Adapted from: Overview of Sensors and Needs for Environmental Monitoring Clifford K. Ho, Alex Robinson, David R. Miller and Mary J. Davis, Sandia National Laboratories, Albuquerque, NM 87185, USA.

same study, the spending of these 5 top spending countries[20] should correspond to roughly 85% of the overall EU public spending, which thus could be estimated to be as high as €235 million.

On top of the public sector spending on data collection, the private data collection sector (€1.6 billion) is roughly double the amount of the public sector (€900 million). This would bring the cost of overall data collection in 2009 to approximately €700 million. This estimation seems to be in accordance with figures provided in more recent publications by the Joint Programming Initiative "Healthy and Productive Seas and Oceans" (JPI Oceans) for 2013, where the annual research budget dedicated to marine and maritime research in Europe is close to €1.9 billion, out of which 40% (appr. €760 million) was spent on marine research infrastructures.[21] As these reports where prepared between 3 and 7 years ago, and the marine monitoring market has shown signs of rapid growth since, it are very likely that these figures should be considered a conservative estimate.

In the following paragraphs, an attempt is made to extrapolate the quantitative nature of the possible benefits, having of course made the necessary assumptions.

6.2.2 *Power consumption*

In terms of energy consumption and the related costs, the amount of money spent here varies greatly and is subject to the type of equipment used, duration of mission, energy source type, etc. Nevertheless, from interviews with industry experts it has been established that low power consumption by the sensors is one of the most important factors in achieving added value, due to the lack of uninterrupted power supply in remote areas. Even though sensors these days have become quite frugal, accepting that there is some sort of energy storage solution utilized, the cost savings from being able to opt for a lower capacity battery solution can prove significant. For example, assuming that a certain instrument consumes on average 1W and it remains in operational mode for 10 months every year, in total that amounts to around 7 kWh of energy consumption yearly. Industry experts have pointed out that the, all rising, cost of batteries is expected to reach the area of € 9,000 /kWh in 2018[22]. Hence, a small decrease of 10% in the power consumption of a single instrument is capable of reducing the initial costs (in the form of battery acquisition) by more than € 6,000. On top of that, the cost of the energy itself should be added, a cost that cannot be identified clearly, as it varies greatly between different areas and for different sources. Additionally, lower energy consumption can lead to weight reductions system-wise, as lower energy capacity solutions have less weight, added then to the weight reductions coming from instruments with lower size and weight. Storage solutions have generally a capacity to weight value of 600 kWh/kg therefore the same 10% decrease of instrument consumption that was discussed earlier, can potentially lead to more than 10 gr reductions in system weight, per instrument. Less power-consuming sensors might also allow for longer measurement duration. This has proven to be a significant contributor to operational cost reductions in the case of float- and glider-based measurements as seen in the task 3.6 analysis of use cases (see deliverable D3.6). In the use case where the PROVOR float has been used in combination with the A1 sensor; it has been calculated that a 10% prolongation of sensor operation comes with a mere 4% increase in overall use case costs due to the relative reduction of CAPEX significance.

6.2.3 *Capital costs*

To begin with, the instrument acquisition costs have to be mentioned. As described earlier, scientific instruments are very precise type of equipment and, as such, tend to be very expensive. For a fully equipped standard ocean observatory, the initial investment needed for the sensors only amounts to almost € 100,000 [23], making up some 20% of the total initial costs. Then, one has to take into account that such equipment has a steep depreciation rate that can exceed the 5% mark, on a yearly basis. With that in mind, it can be concluded that a 10% decrease in capital costs of scientific instruments brings a 2% decrease in initial total costs and a further 0,5% decrease in operational costs per

[20] Same country selection, only replacing Sweden with Italy.
[21] European Commission, Towards European Integrated Ocean Observation, Expert Group on Marine Research Infrastructures, Final report (2013).
[22] Roland Rogers, National Oceanography Center, From his presentation titled "Advancing Deep Sea Operations for Unmanned Vehicles" given during OI 2016.
[23] Cost and value of multidisciplinary fixed-point ocean observatories, Luisa Cristini a,n, Richard S. Lampitt, Vanessa Cardin, EricDelory, Peter Haugan, Nick O'Neill, George Petihakis, Henry A. Ruhl.

instrument yearly.

6.2.4 *Maintenance requirements (Antifouling technology)*

Moving forward, one of the most cost-intensive elements of environmental monitoring is identified, that of vessel costs. The instruments taken into account in this study concern measurements in water environment and, as such, the use of vessels is necessary to access the deployment site. Usually, research organisations rent a vessel as necessary and endure the, sometimes severe, costs that this entails. As seen in Table 6-2, the costs of renting a vessel suitable for environmental survey purposes amount to $18.000 on average[24]. Compared to other, more specialised, types of vessels, this is indeed a relatively low cost.

TABLE 6-2: COSTS OF RENTING VARIOUS VESSEL TYPES[25]

Vessel Type	Day Rate (thousands, current values)
Environmental Survey	$ 12-24
Geophysical Survey	$ 18-22
Geotechnical Survey	$ 60-100
Logistics	$ 180-400

Therefore, all sensor developments covered in previous paragraphs that lead to less need for site visits, imply cost savings of at least € 16.000 per day saved. Other sources provide even higher figures for vessel costs, reaching up to € 20.000 /day[26], revealing the significance of the related costs.

Data from 2009 concerning 5 EU countries[27] report the cost of operating the publically funded data collecting fleet for these 5 coastal countries to € 209 million for a total of 14,347 days at sea. This brings the cost of the average vessel-day in Europe to approximately € 14,500. The average cost of private sector vessels seems to be even higher with an average of € 27,700 /day being reported as an appropriate value. This brings the weighted average to approximately € 22,850 /day in current values.

TABLE 6-3: COSTS OF USING PUBLIC AND PRIVATE SECTOR VESSELS[28]

Source of funding	Average vessel day rate (current values)	Sector size (in € million, current value)
Public data collecting sector	€ 14,500	1,014
Private data collecting sector	€ 27,700	1,748
Weighted Average	**€ 22,850**	

This means that a moderate decrease in workload achieved by the NeXOS innovations that could lead to a faster vessel turnaround rate when visiting/maintaining monitoring platforms or performing measurements or even a decrease in the number of trips needed as a result of the better performance of the antifouling system, can lead to a cumulated cost saving of a minimum of a couple of vessel-days per year. Should no further maintenance be needed, the antifouling improvement alone can reduce the maintenance cycle from once every three months for coastal monitoring and once a year for deep sea monitoring[29] to once every three years. Assuming a minimum of one vessel-day per

[24] Note that rental rates of ships can be highly volatile depending on market conditions, demand and supply.
[25] Adapted from: Overview of Sensors and Needs for Environmental Monitoring Clifford K. Ho, Alex Robinson, David R. Miller and Mary J. Davis, Sandia National Laboratories, Albuquerque, NM 87185, USA.
[26] Cost and value of multidisciplinary fixed-point ocean observatories, Luisa Cristini a,n, Richard S. Lampitt, Vanessa Cardin, Eric Delory, Peter Haugan, Nick O'Neill, George Petihakis, Henry A. Ruhl.
[27] The UK, the Netherlands, France, Spain and Sweden.
[28] Adapted from MRAG, Marine Data Infrastructure, Executive summary, 2009.
[29] L. Delauney et al, Biofouling protection for marine underwater observatories sensors, Oceans 2009 – Europem May 2009, Page 1-4 (2009).

maintenance round for deep sea monitoring and half a day for coastal monitoring we can estimate a moderate potential cost saving of € 53,250 for coastal monitoring and € 15,000 for deep sea monitoring.

TABLE 6-4: POTENTIAL COST SAVINGS OF ANTIFOULING IMPROVEMENTS FOR VESSEL

Source of funding	Annual maintenance rounds due to fouling	Annual vessel-day savings	Approx. vessel cost savings (in € annually)
Coastal monitoring	Approx. 5	2.33	53,250
Deep sea monitoring	1	0.66	15,000

Source: Delauney et al., 2009.

6.2.5 *Interface interoperability*

Beyond vessel costs, another important factor contributing to costs is personnel costs. This can differ significantly for different monitoring platforms and operational set-ups. For more complex set-ups personnel costs are expected to represent a larger part of the overall operational costs. An example of highly complex operations is that of operating a network of full-depth observatories similar to the one prepared by the FIXO³ project for such projects, personnel costs can mount up to half of the overall costs. In the cost benefit analysis of the FIXO³ observatory network, personnel cost are estimated to €364.000 /year, comprising nearly 50% of the overall monitoring costs (€731.000 /year).[30] The added value of the NeXOS sensors plug and play capability becomes obvious when considering that a mild reduction of 10% of personnel time can lead to an overall 5% reduction in annual network operating costs (approx. €36.000 /year). However, the interface interoperability developed in NeXOS is considerably reducing platform-sensor combination time. To give a slight indication, driver development time has been reported by NeXOS project partners to consist of up to 80% of the time required to set up a platform. The Balearic Islands Coastal Observing System suggests a glider set up time prior to a mission to be up to 42 hours[31]. Even a moderate decrease estimation of workload of 10% can lead to a minimum of costs savings of € 200 /mission, according to the average costs of personnel reported by FixO³ (Cristini et al., 2013). Interviews with industry experts have highlighted further that the plug and play capability developed makes redundant the need to develop protocols for platform/sensor combinations. This amounts to between 1 day and 1 week every time a new sensor type is used and a couple of hours every time a new individual sensor is used. Resulting to an overall cost reduction of approx. € 4,000 (half the cost of an O1 sensor) when using a new sensor type decreases the barrier for non-specialised organisations to enter into environmental monitoring. Overall, this NeXOS innovation lowers significantly the threshold to operating sensor-based monitoring systems as along the reduced time requirements, also the reduction in appropriate skills requirement enables organisations with less technical profiles to become involved.

6.2.6 *Quality of measurements – data interoperability*

Quality of measurements is another area where possible economic benefits can arise. In water quality related measurements, it has been documented that up to 80% of associated costs can be linked to laboratory analysis[32]. This is because there is a great level of uncertainty within the processes involved, including storage, transportation and analysis, with a high risk of compromising the results. Instruments that provide high quality in-situ measurements remove the need for laboratory analysis and, therefore, the risk and costs that go with it. Past studies have concluded that a total cost savings of 26.2% can be achieved with systems that implement interoperable standards[33]. The task 3.6 use

[30] Cristini L. et al. FixO³ D6.6 Cost-benefit analysis report.
[31] S. Cusi, Torner M., Martinez-Ledesma M., Roque D., Beltran J.P., Ruiz S., Casas B., Castilla C., Lizaran I., Lora S., Heslop E., Tintore J., On the setup of an operational autonomous underwater glider facility, 2013.
[32] Overview of Sensors and Needs for Environmental Monitoring Clifford K. Ho*, Alex Robinson, David R. Miller and Mary J. Davis Sandia National Laboratories, P.O. Box 5800, Albuquerque, NM 87185, USA.

[33] Booz Allen Hamilton – NASA Geospatial Interoperability Office, Geospatial Interoperability Return on Investment Study, 2005

cases highlight how light data processing becomes after the application of data interoperability standards as data processing now requires less than an hour spent by relevant personnel.

Moreover, as shown in the relevant causal diagrams previously, better data open up the possibility for revenue streams from data selling. In 2001, the revenue accrued from data sales in the UK public sector was around 1% of turnover[34]. As illustrated in the beginning of this paragraph, the EU public data collection sector is estimated to around 1 billion € and, assuming the revenue from data sales remains the same in percentage terms, data sales are estimated to a total value of € 10 million /yeary. It is important to note here that this is a rather conservative estimation as the needs for ocean monitoring have grown significantly since 15 years ago, hence the need for data is much larger now. With that in mind and coupling also the benefits created by data interoperability, a potential increase in marine environment observation data sales of 50% signifies additional revenue of € 5 million /year, just for the public sector, where in most cases data are provided free of cost. Taking a look at the private sector, which is almost twice the size of the public sector and data is not provided free of cost, one can expect that at least another € 10 million in additional revenue can be generated. All in all, under some conservative assumptions, additional revenue from data sales can easily reach € 15 million per year for the EU market alone, because of positive developments in data quality and interoperability.

6.3 NeXOS benefits and cost savings per innovation

In this section, the specific benefits brought to each of the NEXOS sensors are discussed. Further, an approach to quantify the potential added value of these benefits is adopted with the aim not to present rigid values but rather present the scale of the benefits potential. Furthermore, all the NeXOS transversal integrations are regarded not individually, but as an integrated part of the sensors and instruments developed in NeXOS, in order to showcase their effect in a tangible manner.

6.3.1 *NeXOS innovation A1 – Acoustic sensor*

The NeXOS A1 innovation as described in paragraph 5.1.1, is a compact, low-power, multifunctional digital passive acoustics sensor system, enabling on-platform measurement and characterisation of underwater noise and several soundscape sources, aimed for platforms with limited autonomy and/or communication capability. In essence, A1 is a digital hydrophone that offers embedded processing. It is a solution of which the size, data interface capabilities and power consumption make it ideal for use with multiple types of platforms where undisturbed power supply is not an option. The comparison with other available, relatively similar, products available in the market today revealed that this NeXOS innovations brings significant benefits in the areas of capital costs, physical properties, power consumption, quality of measurements as well as interface and data interoperability. More specifically, A1 brings a 60% decrease in capital costs, amounting to around €6.000 per instrument and has smaller dimensions, especially in terms of diameter. Moreover, A1 performs rather well in the area of power consumption with, up to 3 times lower energy consumption in operating mode, a figure corresponding to 2 W less than the competition. Assuming uninterrupted year-round operation of the instrument that leads to 17kWh of energy savings. Finally, next to the plug and play capability and data interoperability, A1 has 35% higher sensitivity, hence better measurements quality.

TABLE 6-5: THE POTENTIAL OF THE NEXOS A1 BENEFITS AND ADDED VALUE

Type of benefit	Benefit potential	Quantification of added value
Capital costs	60% decrease	€ 6,000 per instrument
Power consumption	66% decrease	Up to 17 kWh yearly
Physical properties	40% decrease	Around 20 mm in diameter

[34] Rayner, Dr. R., Smallman, Dr. J., Cameron, Dr. G. & Wallace, Dr. C. (2003) Achieving optimal value from publicly funded marine information resources. UK Marine Information Council.

Measurements quality	35% increase	++

6.3.2 *NeXOS innovation A2 – Acoustic sensor*

As explained in paragraph 5.1.2, the NeXOS A2 innovation is defined as a compact multifunctional passive acoustics sensor system, enabling real-time waveform streaming for the measurement of underwater noise and several soundscape sources, aimed for platforms with unlimited autonomy and/or communication capability. In essence, A2 is an array of passive acoustic sensors, synchronized so as to work together and provide additional functionalities such as detection of the sound's direction of arrival. More specifically, A2 is an array of four digital hydrophones similar to A1 and a Master Unit (A2M) that receives the signals in synchronous mode using Ethernet interface. The main benefits coming from this innovation are in the areas of capital expenditure, physical properties, power consumption, quality of measurements as well as interface and data interoperability. In further detail, A2 brings a 37,5% decrease in capital costs, amounting to € 15,000 per system and has a smaller total size, as it makes use of the smaller A1. More importantly, compared to the competition, it has a 50% lower energy consumption, a reduction that equals to 4W of less energy assuming arrays of 4 hydrophones. Assuming uninterrupted year-round operation of the system, that leads to around 35kWh of energy savings. Finally, due to the A1 benefits, the system takes advantage of the A1 plug and play capability, data interoperability and 35% higher sensitivity.

TABLE 6-6: THE POTENTIAL OF THE NEXOS A2 BENEFITS AND ADDED VALUE

Type of benefit	Benefit potential	Quantification of added value
Capital costs	37,5% decrease	15.000 € per system
Power consumption	50% decrease	Up to 35 kWh yearly
Physical properties	Decrease	Depending on set-up
Measurements quality	35% increase	++

6.3.3 *NeXOS innovation O1- Optical sensor*

The NeXOS O1 innovation was described in paragraph 5.2.1 as a compact, low-power, multifunctional optical sensor system based on multi-wavelength fluorescent technology, providing detailed information on water constituents as well as other relevant contaminants being optically active in the respective spectral region. The O1 sensor measures four parameters, namely coloured dissolved organic matter (CDOM), Chlorophyll-a, polycyclic aromatic hydrocarbons (PAH) and Turbidity. NeXOS O1 brings benefits in the areas of capital expenditure, operational costs, physical properties, power consumption, quality of measurements and multifunctionality. The reduced size, weight and power consumption allow for longer monitoring missions and the use of smaller (more economical) and alternative platforms (increasing the environmental monitoring market). O1 is a unique instrument, meaning that no other solution could be identified in the market, capable of measuring the same mix of parameters. A combination of at least two existing competing solutions is needed to measure at least the same parameters. More specifically, O1 provides a 30% decrease in capital costs, amounting to around €4.000 and is almost half the size of a comparable instrument combination. Furthermore, it brings a 54% reduction in energy consumption that equals to 2,9W of less energy or 25kWh on a year-round uninterrupted operation basis. On another point, the innovative antifouling technology allows for 36 months of unhindered operations, bringing cost savings of around €50.000 on a yearly basis. To conclude, it matches the range of existing solutions but has higher accuracy, especially in Tryptophan measurements.

TABLE 6-7: THE POTENTIAL OF THE NEXOS O1 BENEFITS AND ADDED VALUE

Type of benefit	Benefit potential	Quantification of added value
Capital costs	30% decrease	€ 4,000 per instrument
Operational costs	40% decrease	At least € 350 per year saved in costs of spare parts
Weight	3-5 kg reduction	Weight decreased by nearly 90% compared to average case. Enables longer missions and mounting to smaller platforms (leading to reduced operational costs)
Power consumption	54% decrease	Up to 25 kWh yearly
Physical properties	Around 50% decrease	Depending on competition set-up
Maintenance	36 months without maintenance	Depending on mission (up to 50.000 € annually due to non use of vessel)
Measurements quality	Increase	+
Multifunctionality	Unique parameters combination	+++

6.3.4 *NeXOS innovation O2 – Optical sensor*

As seen in paragraph 5.2.2, the NeXOS project, referred to as O2, is described as a compact, low-power and multifunctional optical sensor system based on hyperspectral cavity absorption technology, enabling measurement of water constituents such as dissolved organic matter, suspended matter, and phytoplankton. The O2 not only has better physical properties but is also frugal in energy needs and cheaper to acquire. More specifically, it is 15% less capital intensive, a decrease that amounts to around €4.000 per instrument, 25% smaller in diameter and, on top of these advantages, has impressive power consumption needs, 80% lower than the competition products and weight reduced by 80%. Energy savings alone, amount to 20W less energy consumption or 170kWh on a year-round uninterrupted operation basis. The reduced size, weight and power consumption allow for longer monitoring missions and the use of smaller (more economical) and alternative platforms (increasing the environmental monitoring market). Finally, the instrument incorporates the innovative antifouling technology, allowing for lower maintenance needs and uninterrupted operation of 36 months.

TABLE 6-8: THE POTENTIAL OF THE NEXOS O2 BENEFITS AND ADDED VALUE

Type of benefit	Benefit potential	Quantification of added value
Capital costs	15% decrease	€ 4,000 per instrument
Power consumption	80% decrease	Up to 170 kWh yearly
Weight	80% decrease	About 12 kg
Accuracy	Significant increase	Enables more accurate scientific measurements.
Physical properties	Around 25% decrease	Depending on competition set-up
Maintenance	36 months without maintenance	Depending on mission (up to 50.000 € annually due to non use of vessel)
Plug and Play	As explained previously	+++

6.3.5 *NeXOS innovation - O3 Optical sensor*

In paragraph 5.2.3, the NeXOS O3 innovation was described. O3 is a compact, low-power, multifunctional carbon sensor system. Such sensor arrays are used to quantify the marine carbonate system by combination of a high precision sensor for pH and AT together with a membrane based pCO2 sensor. The O3 system includes high precision spectrophotometric pH and carbonate ion sensor with a membrane based pCO2 sensor. Furthermore, the O3 innovation comes in two types of array namely Cbon2 (measuring pH and pCO2) and Cbon3 (measuring pH, pCO2 and AT). Cbon2 array has two different layouts, one for ferry box deployment and one for surface vessel deployment. Besides the benefits coming from the incorporation of the transversal innovations and the multiple platform operability, there is a lack of information on the competing products, making it difficult to recognise any potential benefits in other areas.

TABLE 6-9: THE POTENTIAL OF THE NEXOS O3 BENEFITS AND ADDED VALUE

Type of benefit	Benefit potential	Quantification of added value
Multifunctionality	2 to 3 parameters measured	Unknown
Maintenance	36 months without maintenance	Depending on mission (up to 50.000 € annually due to non use of vessel)
Plug and Play	As explained previously	+++

6.3.6 *NeXOS innovation – EAF monitoring system*

The NeXOS EAF sensor system innovation is a unique development that greatly facilitates the unfolding of the Ecosystem Approach to Fisheries. In this case the NeXOS innovation brings forward technological developments that facilitate the unfolding of this approach at a considerably lower cost level by enabling the relevant measurements to be performed by the regular fishing fleet without requiring a significant increase in activities or costs of fishing.

The EAF has been considered to bring significant benefits including not only economic benefits such as increased fish catches, reduced fishing costs and higher value catches, but also ecological benefits such as producing healthier ecosystems and reducing threats to endangered species and a number of socio-economic and management benefits linked to fisheries. Charles and Anthony (2009) provide an inclusive list of costs and benefits of the EAF distinguishing economic, ecological, socio-economical and management aspects. The benefits of the EAF approach are considered to greatly outweigh the costs, but due to the high introduction costs, the EAF application has not yet been applied across the EU. Rational economic thinking would suggest that in these cases, eventually a mechanism would be introduced to harvest the great economic benefit. The production of a functional and cost-effective EAF system as a result of the NEXOS innovations may result in the acceleration of the introduction of the EAF.[35]

Currently, there is no system equivalent to EAF. Nevertheless, there are some manufacturers (Star Oddi from Iceland) that offer a limited series of loggers for temperature, depth and salinity. However, these do not offer the functionalities of the EAF system and have no communication systems. Furthermore, trawl positioning systems can be equipped with limited sensor systems (again measuring temperature and depth) but they use real time communication systems via a necessary acoustic base on the vessel, making them very costly. The main advantages brought by NeXOS EAF are twofold: very low operational costs and quality of measurements. Operating expenditure is minimized with EAF as there is no longer the need to rent a research vessel in order to perform the measurements (the volunteering fishing vessel is used instead) and communications take place after the completion of the measurements, via common communication networks. Such communication costs can be less than 10 euros per month. Regarding quality of measurements, the EAF system provides the opportunity to make a stable profiling from surface to depth of 300 meters, using the fishing gear. This type of result

[35] Charles, Anthony, de Young, Cassandra, Benefits and Costs of Implementing the Ecosystem Approach to Fisheries, chapter in The Ecosystem Approach to Fisheries, edited by Bianchi, Gabriella and Skjoldal, Hein R., 2009.

can be very difficult to obtain otherwise, for example using a drifting buoy. Additionally, EAF system includes loggers for oxygen and fluorescence, providing scientists with more relevant information that can, in turn, result in better catches for the fishermen.

In the light of the above, we can suggest that the NeXOS innovation is a major contributor to achieving the benefits of EAF but we can certainly not attribute the whole amount of EAF benefits to NeXOS. Attempting to attribute a part of the benefit to the NeXOS innovation would be more appropriate, however there is no secure way to distinguish the amount of benefits that we could attribute to the NeXOS innovations. Thus, in this report, we are not presenting a quantification of the benefits of the NeXOS innovations due to enabling the EAF.

6.4 Limitations of added value assessment

The assessment of the added value of the NeXOS innovations has been an arduous process which has encountered a number of barriers that needed to be tackled:

- NeXOS product development was still ongoing at the time of the original submission date of this deliverable, so that significant data was not available. Also the process of operationalising the NeXOS product was not, and still is not yet fully complete, rendering the estimation of (especially) operational costs additionally difficult.
- NeXOS products are unique, for most of them there are no comparable instruments in the market performing the same functionalities. As such, comparison can only be performed on a theoretical level and regarding specific aspects. This will necessarily leave out of scope of the comparison some of the main NEXOS innovations capacities, such as the possibility to measure new parameters. To showcase the advancements, combinations of products have been taken into account, under the assumption that these are possible and the competing products can co-exist simultaneously.
- Availability of information especially regarding competition is scarce. It has been very hard to obtain CAPEX and OPEX figures from non-NeXOS manufacturers as they are not willing to disclose these information to non-customers. Where possible estimations from users have been applied; however this is also constrained by the limits in the thinking of the users in matters of complete operational (life-cycle) costs.
- Components of OPEX are, for a big part, usage related and mission specific. These figures can only be estimated given the fact that the products are not yet fully developed and used in real situations. Critical estimations had to be made (e.g. regarding frequency of maintenance, workload for data processing etc.) based on expert judgements of users, rather than based on measurements of actual processes. In this respect, we have devised a number of use cases to theoretically and consistently assess the operational costs under various monitoring set-ups of sensor/platform combinations.
- As indicated in deliverable D2.1, in relation to market size and economic assessments, very limited to no relevant information has been found. Additional effort was put in reviewing the public documentation of other Horizon2020, FP7 / Oceans of Tomorrow research projects. It appeared that those projects did not contain dedicated market analysis or added value assessments, and the effort undertaken under NeXOS WP2 is unique in its level of detail. Despite efforts to reach out to other research teams for exchange of non-public information, this has not been met with fruition. Eventually the quantification of costs and estimations of market developments has been based on whatever data has been found available including incremental and older information.

6.5 Summary

This section presents an overview of the types of cost savings and benefits for each of the NeXOS sensor innovations, including the impact of the transversal innovations thereof. Furthermore, each type of improvement is assessed as to the added value and evaluated as small added value (+), medium added value (++) or large added value (+++) as presented in Table 6-10.

Table 6-10: Assessment of benefits and cost savings of the NeXOS innovations

NeXOS improvements	A1	A2	O1	O2	O3	EAF
Physical properties	+	+	+++	+++	++	+++
Power consumption	++	+	+++	+++	+	++
Multifunctionality	++	++	+++	+++	+	+++
Capital & operational costs	+++	++	+++	++	+	+++
Operational depth	+	+	+	++	+	+
Quality of measurements	++	++	+	+++	++	++
Maintenance (antifouling)	-	-	+++	+++	+++	++
Interface interoperability	++	+	++	+++	+++	+++
Data interoperability	+++	+++	++	++	++	++
-: not applicable						

7. NEXOS MARKET POTENTIAL

In this chapter we aim to assess the market potential for the NeXOS innovations. In this regard, we discuss how the benefits of each of the sensor and transversal innovations achieved by NeXOS can lead to a larger market share for the European sensor-industry.

7.1 Routes to market uptake

The NeXOS innovations create the potential for the European sensor industry to pursue a larger market uptake. This is due to the benefits brought by the NeXOS improvements to sensor attributes which are critical to sensor users. We identify in this respect three potential routes to market uptake for the NeXOS sensors:

- Expanding their share in existing markets (e.g. by outperforming competition);
- Creating the potential to increase market size as a result of improved NeXOS characteristics (e.g. by facilitating measurements or due to the introduction of new product and services);
- Enabling the use of the NeXOS sensors in new market segments.

In the next section we discuss how the NeXOS innovations fare in aligning the benefits they produce with the needs of end users for different market segments and achieving market uptake along these three routes.

7.2 Evaluation of market uptake per Innovation

As each of the NeXOS innovations has different scope and performs different types of measurements, it is understandable that they serve different markets or combinations thereof. Consequently, in the following paragraphs, the expected market uptake will be discussed, on an innovation level.

7.2.1 *NeXOS A1 market uptake*

As introduced in the previous section, sensor A1 carries the potential for significant benefits as a result of the improvements it delivers. The A1 sensor outperforms competition in a number of fields which make probable market uptake in all three different routs defined.

Improved physical properties and power consumption facilitates the use of the sensor in more challenging settings as they lower platform requirements. Combined with the decrease in capital and operating costs, these improvements are expected to boost uptake in the applications of this sensor system related to monitoring of marine mammals for the sectors of offshore & gas industry and offshore renewable energy in the short term replacing competitive systems. Such operations might be mainly driven by costs and operational concerns, however the multi-functionality improvements of the A1 enable better monitoring of the MSFD requirements. In the long term, deep sea mining is a developing sector where the NeXOS innovations can substitute traditional monitoring techniques.

Considering oceanographic research, passive acoustic measurements of better quality are now enabled alongside a somewhat increased operational depth. Therefore, the innovations of NeXOS on themselves are expected to increase the market for sensors overall. Finally, a further boost is expected for A1 as it constitutes an integral part of the innovative NeXOS A2 system. As that becomes more widely accepted and recognised, the A1 instrument will become more important and enjoy a further boost as the stepping stone towards the A2 system.

7.2.2 *NeXOS A2 market uptake*

According to the description of the A2 passive acoustic sensor system as given previously, this NeXOS innovation is a combination of four A1instruments, synchronised through a master unit. Therefore, the A2 system enjoys all the benefits that A1 brings and, subsequently, has a similar market uptake potential. As with A1, the A2 system brings significant benefits in power consumption, capital costs and measurements quality only multiplied by a factor of 4, as many as the number of

A1instruments in the system.

With that in mind, the NeXOS A2 system is expected to have an even larger uptake, at least on the same markets as A1. As such, the improvements that A2 brings are expected to significantly boost uptake in the applications of this sensor system related to monitoring of marine mammals for the sectors of offshore & gas industry and offshore renewable energy. However, the A2 sensors system brings a potential of revolutionising port security monitoring as they provide a substitute for sonar-based monitoring. The capability of A2 to locate the source of the sound renders it appropriate for use in military operations, in order to locate underwater threats.

Furthermore, the interoperability improvements of the sensor related to interfaces and data, render the use of these sensor systems in this market segment easier for service providers or end users directly. Eventually, the NeXOS innovations produce a promising potential for introducing passive acoustic measurements in this new market segment.

7.2.3 *NeXOS O1 market uptake*

The NeXOS O1 optical sensor is a unique instrument. At first, the combination of measured parameters it offers places it in a category of its own, as no other single instrument in the market has the ability to match it. That unique combination makes this instrument relevant for a multitude of markets, namely monitoring of environmental quality, offshore oil & gas, industrial water quality measurements, oceanographic research, aquaculture as well as deep sea mining.

At first, the most significant of improvements brought by O1 is the combination of extreme reduction of power consumption, size and volume. This allows for uninterrupted and longer operations, a quality of high importance for costly applications that require high accuracy, as usually found in the oil & gas and deep sea mining sectors. These properties next to the reduced operational costs, allow also for the use of smaller and alternative platforms which could potentially reduce costs across all markets but especially giving a boost new markets.

Next to that, limited maintenance needs lead to quantifiable benefits that can prove considerable. For sectors such as environmental monitoring and oceanographic research, where budgets can be tight, O1 in essence pays back its acquisition cost multiple times by reducing the costly maintenance operations. Coupled with the innovative multi-functionality, lower power consumption and lower capital cost, O1 is expected to have a swift and large uptake in these markets.

Finally, the ability of O1 to operate on a variety of platforms and the interoperable data it provides makes it possible to capture market share in sectors where such instruments are not necessary but could work supplementary e.g. aquaculture.

7.2.4 *NeXOS O2 market uptake*

The NeXOS O2 optical sensor system enables measurement of water constituents such as dissolved organic matter, suspended matter, and phytoplankton with a different method used here, that of cavity absorption. As instruments that operate within the same concept tend to be very expensive, the decreased capital cost of O2 is expected to make this technology viable to a wider audience. The sector of aquaculture is an example, where O2 can find new grounds of usage.

In the traditional sectors that use this type of sensor such as environmental monitoring, oceanographic research and water quality measuring, the benefits of O2, especially in the form of limited power consumption, reduced size, weight and maintenance needs, are expected to boost market uptake rather significantly. These properties allow also for the use of smaller and alternative platforms which could potentially reduce costs across all markets but especially giving a boost to the under-developed and rowing market applications. As seen previously, these benefits are capable of producing added value that, in monetary terms, exceeds the sensor acquisition within a relatively short period of time. Hence, the NeXOS O2 sensor is expected to show a powerful market uptake, as it makes acquiring such expensive technology a reasonable choice and a viable business case.

Additionally, the innovative measurement process and consequent increased accuracy, allows for more demanding scientific applications. Of course, sectors where this technology is necessary, irrespective of the cost, will also benefit from the limited maintenance and energy consumption characteristics. Therefore, NeXOS O2 is expected to be the instrument of choice, also for such cases.

7.2.5 *NeXOS O3 market uptake*

Similarly to the rest of the optical NeXOS innovations, the O3 is characterised by extensive advancements in the fields of energy consumption and maintenance needs, due to the innovative anti-fouling technology. Furthermore, the unique multi-functionality of the O3 system and its ability to operate in a variety of platforms, makes it a solution that fits a wide range of applications with different needs. Therefore, O3 is expected to be the instrument of choice when it comes to measuring respiration, photosynthesis and relevant parameters in freshwater or other ecosystems. The advantages of the O3 system, as they were covered in previous paragraphs, are expected to boost uptake in markets such as Monitoring of environmental quality, oceanographic research and water quality measurement as well as open up the possibility of more extensive use for the sector of aquaculture.

7.2.6 *NeXOS EAF market uptake*

The Ecosystem Approach to Fisheries management (EAF) is a combination of the several optical and passive acoustic instruments developed within NeXOS. The EAF allows for gathering more precise data on the spatial distribution of the catch and the fishing activities involved. The system can also be used to assess the quality of the fish stock, e.g. the weight and size of the fish. As such, EAF takes advantage of the combination of benefits brought by all of the NeXOS innovations.

Therefore, it is a system with very low power consumption, high measuring accuracy and user-friendly, with multiple interface capabilities and data interoperability. On top of that, the total system is much easier to acquire, due to the low capital costs of the NeXOS components. In consideration of all these qualities it is expected that the EAF, as a system that is easy to acquire and install on regular fishing vessels, will have significant market uptake in the sector of fishing and aquaculture. Additionally, the data produced by this system is relevant for researchers monitoring environmental quality, hence the system will be also relevant in those markets.

7.2.7 *NeXOS Antifouling Innovation market uptake*

Moving over to the transversal NeXOS innovations, the anti-fouling technology developed within this project is discussed. This technology removes any moving parts, a technique that was used in traditional sensors, allowing for far better anti-fouling performance. The result is instruments that are able to be operational for up to 36 months, without experiencing any deterioration in quality of measurements.

The impact of such an innovation is paramount. As described in previous chapters, lower maintenance needs lead to less deployment site visitation, a process that can be extremely intense in terms of costs, duration and effort. At this point, it is necessary to mention that the antifouling technology is relevant to applications that use optical sensors, hence the benefits and the market uptake of this innovation are inherently linked to these of the respective sensors. Nevertheless, as the antifouling innovation is independent, it can be used on any other optical sensor, besides NeXOS. Therefore, based on the immense effects that minimisation of maintenance needs can have, it is expected that the NeXOS antifouling innovation will have a large uptake in all the optical sensor-relevant markets.

7.2.8 *NeXOS Interface interoperability innovation market uptake*

In the NeXOS project, instrument interface interoperability is advanced through the development of a plug-and-play system that enables the usage of all sensor types on all different platforms (buoys, gliders, vessels etc.), without the need for extensive adaptation efforts and relevant software development. These reduced threshold, in matters of both time and skills availability, increases the probability of less technical-oriented organisations to independently embark into environmental monitoring activities.

In the previous chapter, it was illustrated how this specific innovation leads to lower overall costs in at least four different ways. As such, this specific NeXOS innovation is expected to gain large momentum in every market that entails the use of sensors, even outside the water environment. Nevertheless, this momentum will only come in the long-term, as, first, the existing methods and options have to be adapted and, second, eventual teething problems of the NeXOS interoperability innovation have to be ironed-out.

7.2.9 *NeXOS Data interoperability Innovation market uptake*

Finally, the last NeXOS transversal innovation is regarding data interoperability. In that sense, the use of universal data platforms removes the problem of unusable data, due to specialised or custom made formats, applicable only to certain sensors of specific manufacturers. There is a great potential with this innovation, to create a global database of data that can be accessible by anyone who has an interest. Therefore, scientists and other interested parties can simply retrieve the data they need, avoiding the hefty costs that the preparation and execution of a mission entails.

For these reasons, much like the previous transversal innovation, NeXOS data interoperability advancements are expected to have a large uptake in all sensor-relevant markets, albeit in the long-term. Besides the opposition of competing manufacturers which see a potential open data system as a threat to their market share, there is also the need for security and secrecy of data, especially in the oil and gas sector. Such operations demand for customised protocols and cannot be expected to opt for any widely interoperable data platform. Last but not least, such widely usable data will open the door towards the development of new business models that might not be viable previously, such as a pure data provider service.

7.3 Summary

At this point, it is now clear how the NeXOS innovations impact the monitoring and other relevant processes, in what way value is added, the significance of this value in monetary terms as well as the effect it will have on the assimilation of the NeXOS innovations by the various markets, existing ones and new. In an attempt to summarize the findings of this chapter, Table 7-1 illustrates the expected market uptake of each of the NeXOS innovations, where the direction of the arrows signifies expected growth or decline whereas the number of arrows illustrates the expected magnitude of said effect.

TABLE 7-1: EXPECTED MARKET UPTAKE OF THE NEXOS INNOVATIONS

NeXOS innovation	Existing markets	Increase markets	New markets
A1 – Acoustic	Offshore oil & gas Offshore renewable energy Deep sea mining Ocean renewable energy ↑	Oceanographic Research ↗	Data sales ↗
A2 – Acoustic	Offshore oil & gas Offshore renewable energy Deep sea mining Ocean renewable energy ↑	↑↑ Oceanographic Research	Port security Military applications Data sales ↗
O1 - Optical	Offshore oil & gas Deep sea mining ↑	Monitoring of environmental quality Oceanographic Research ↑	Aquaculture Data sales ↑↑

NeXOS innovation	Existing markets	Increase markets	New markets
		Industrial water quality measurements	
O2 - Optical	Offshore oil & gas Deep sea mining	Monitoring of environmental quality Oceanographic Research Industrial water quality measurements	Aquaculture Data sales
O3 - Optical	Offshore oil & gas Deep sea mining	Monitoring of environmental quality Oceanographic Research Industrial water quality measurements	Aquaculture Data sales
EAF - Combination	–	Monitoring of environmental quality Aquaculture	Data sales
Transversal - Antifouling	Offshore oil & gas Offshore renewable energy Deep sea mining Ocean renewable energy	Monitoring of environmental quality Oceanographic Research Industrial water quality measurements	Third-party sensor development
Transversal – Interface interoperability	All markets		
Transversal – Data interoperability	Offshore oil & gas Deep sea mining	Oceano graphic Research Monitoring of environmental quality Aquaculture Industrial water quality measurements	Data sales

8. SYNTHESIS AND CONCLUSIONS

This report concludes the Task 2.3: Added value of NeXOS innovations, within Working Package 2: Economic viability and industrialisation strategy. As part of this task, the Subcommittee for the Advancement of Small and Medium Enterprise Competitiveness (ASCS) was constituted, initiated and monitored. The responsibility of the ASCS is to ensure that the design and engineering process can be understood and turned into practical implementations by SMEs, industry and the science research and observation community. Within this continuous process, the possible ways to enhance the potential of NeXOS's products has been studied as well as methods and means to penetrate the marine sensor market. As such, the ASCS has been responsible for:

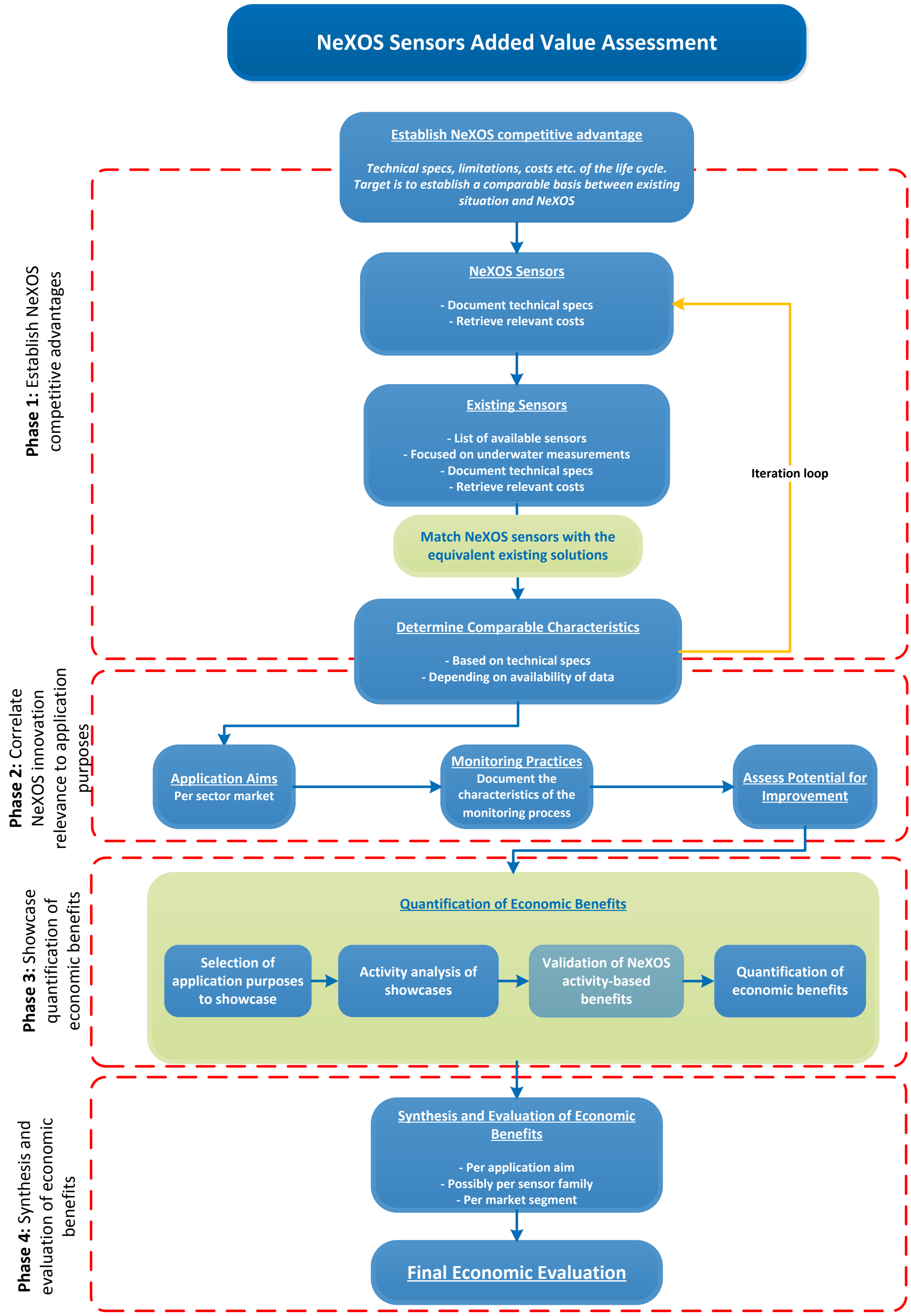
- Creating a short list of success indicators for each of the NeXOS innovations accounting for the most important attributes from a market perspective;
- Setting challenging but attainable aims (targets) for each of the success indicators;
- Steering the innovation development process by updating the aims and success indicators according to market developments when necessary;
- Periodically monitoring progress on the set of success indicators;
- Evaluating progress made on achieving the aim set for each of the success indicators;
- Calling for focus on success indicators where development is lacking;
- Evaluating the attainability of the existing aims and setting alternative aims if necessary trying not to compromise the added value of the innovations.

In total, five ASCS meetings have taken place during which the progress and advancements were discussed, using the integrated traffic-light evaluation scheme to keep up-to-date. As a result, a multitude of improvements have been generated through this process, regarding all NeXOS innovations. The process was unanimously deemed a success hence it was decided by all involved parties to maintain the periodical evaluation of the progress, even after the official end of this task.

Furthermore, in order to assess the economic advantages of the innovations developed within NeXOS, an innovative methodology framework was developed and, consequently, tailor-fitted to the needs of this particular project. The twofold purpose of this methodology is to:

- Identify the main advantages (cost savings in hardware and improvements in operational efficiency, quality etc.), and assumptions (operational lifetime, costs, maintenance needs and replacement rates); and
- Quantify, where possible, said advantages and assumptions in order to arrive to a concrete conclusion regarding the expected market uptake of the NeXOS products.

Besides technical information derived from the other WPs, other inputs and methods were considered, including an exhaustive literature review, interviews and informal conversations with industry experts as well as communications with relevant manufacturers. All inputs were fed into the four-phase added value assessment methodology, as shown below.

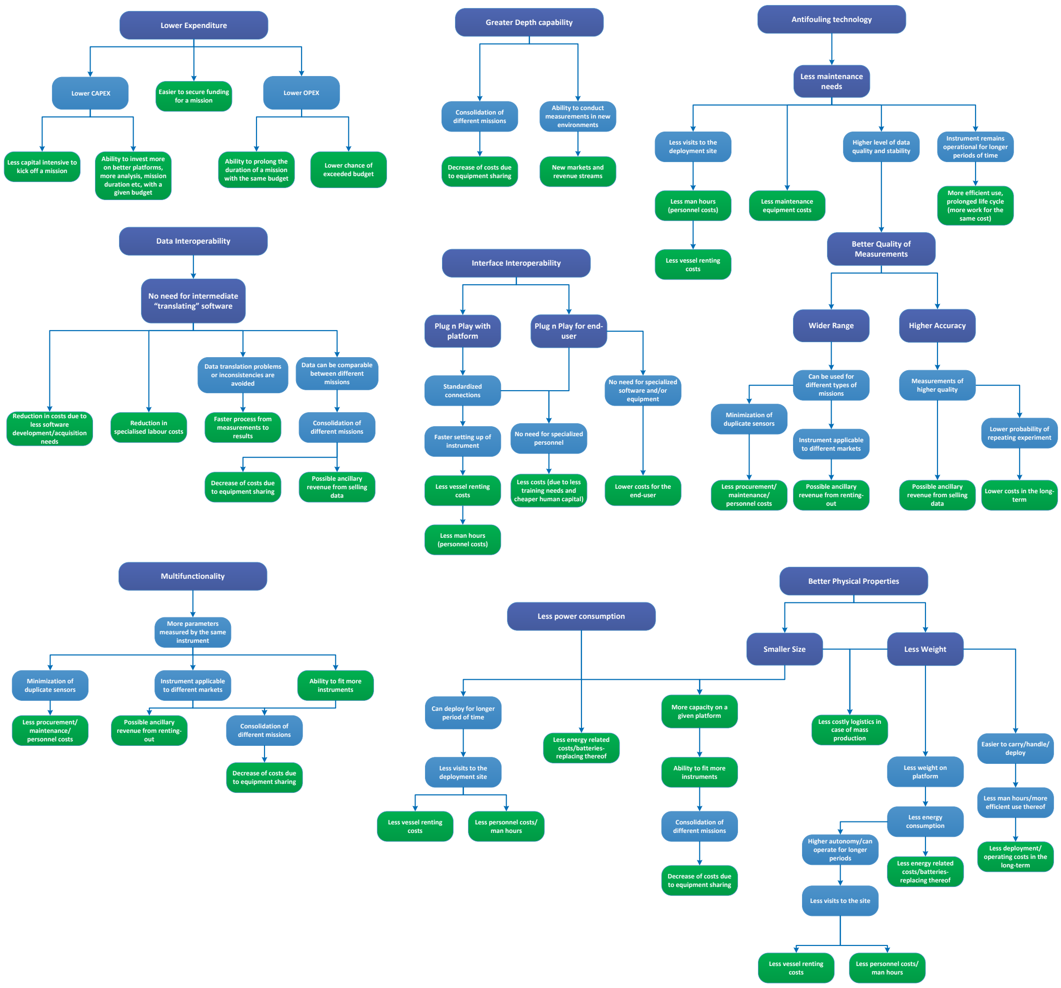


Within that process, the NeXOS products were positioned against the competition. All instruments available on the market that can be, at some level, similar to these of NeXOS were compared side-by-side from both a technical and economic standpoint. The comparison showed that the NeXOS products have significant advantages over the competition, on many levels. Moreover, in many cases, it has been proven that the NeXOS products are currently unique, as no other instrument on the market can offer the same service.

Following the comparison, the identified advantages of the NeXOS innovations, were translated into actual operational benefits. This step has proven crucial towards having a better understanding of how these advantages create added value when they are applied in the field. Causal relationships have been established between a certain advantage and the added value that it can potentially produce, through a series of logical steps that describe the operational variations caused by said advantage. Nine such advantages were identified as key in distinguishing one instrument from another, hence producing added value. These are:

- Physical size – Dimensions;
- Expenditure (CAPEX and OPEX);
- Power consumption;
- Depth rating;
- Multi-functionality (No. measured parameters);
- Quality of measurements (Range and Accuracy);
- Maintenance needs (Antifouling);
- Data interoperability;
- Interface interoperability (Plug 'n Play).

The potential to add value for each of these advantages has been mapped, revealing in total 21 unique routes to added value. The following Figure illustrates these routes as well as the added value synergies between different advantages. The individual routes are presented in separate trees in Chapter 6.1.



In order to quantify these sources of added value, the underwater monitoring market size has been estimated, followed by an overview of the values and costs involved in power consumption, multi-functionality, expenditure, operational depth, quality of measurements, maintenance requirements, interface interoperability and data interoperability. More specifically, in 2009, the five leading member states, accounting for roughly 85% of the overall EU market, have spent €289 million to obtain observation data. The majority of these funds (64%) had been devoted to data collection, leading to the estimation that the data collection EU market measures somewhere in the range of €235 million.

Power consumption, a characteristic that has been found to be of the highest importance, proved to have the potential to bring a rather substantial added value. As explained in the report, just a 10% of energy consumption reduction with an instrument that consumes normally 1W can lead to an astonishing € 6.000 of savings. Keeping in mind that the total sensors for a fully equipped standard ocean observatory cost around € 100.000, the magnitude of the importance that reduced power consumption of just one instrument holds, becomes apparent. Moreover, the analysis showed that the NeXOS antifouling technology has also great potential. Due to reducing the necessity for deployment site visitation, the NeXOS antifouling innovation has the potential to lead to more than € 50.000 of savings on a yearly basis. The quantification of all relevant advantages has then been grouped and assigned to each of the NeXOS innovations. The following tables illustrate a qualitative summary of the potential for added value that each NeXOS product was found to have.

NeXOS improvements	A1	A2	O1	O2	O3	EAF
Physical properties	+	+	+++	+++	++	+++
Power consumption	++	+	+++	+++	+	++
Multifunctionality	++	++	+++	+++	+	+++
Capital & operational costs	+++	++	+++	++	+	+++
Operational depth	+	+	+	++	+	+
Quality of measurements	++	++	+	+++	++	++
Maintenance (antifouling)	n/a	n/a	+++	+++	+++	++
Interface interoperability	++	+	++	+++	+++	+++
Data interoperability	+++	+++	++	++	++	++
n/a: not applicable						

Finally, as sensor users can benefit greatly from the NeXOS improvements, the NeXOS products create the potential for the European sensor industry to pursue a larger market uptake. In that respect, three potential routes to market uptake for the NeXOS sensors have been identified:

- Expanding their share in existing markets (e.g. by outperforming competition);
- Creating the potential to increase market size as a result of improved NeXOS characteristics (e.g. by facilitating measurements or due to the introduction of new product and services);
- Enabling the use of the NeXOS sensors in new market segments.

NeXOS innovations were found to have a positive market uptake potential in the vast majority of cases. Most importantly, it is expected that the markets of monitoring of environmental quality, oceanographic research, industrial water quality measurements and aquaculture will show the greatest prospect for the NeXOS products whereas a positive market share growth is foreseen in the offshore oil & gas and deep sea mining sectors. Finally, new opportunities arise as the NeXOS innovations become relevant for additional markets, particularly those of port security, military applications and data selling. Concluding, the following table summarises the market uptake findings.

NeXOS innovation	Existing markets	Increase markets	New markets
A1 – Acoustic	Offshore oil & gas Offshore renewable energy Deep sea mining Ocean renewable energy ↑	Oceanographic Research ↗	–
A2 – Acoustic	Offshore oil & gas Offshore renewable energy Deep sea mining Ocean renewable energy ↑	↑↑ Oceanographic Research	Port security Military application Data sales ↗
O1 - Optical	Offshore oil & gas Deep sea mining ↑	Monitoring of environmental quality ↑↑ Oceanographic Research Industrial water quality measurements	Aquaculture Data sales ↑
O2 - Optical	Offshore oil & gas Deep sea mining ↑	Monitoring of environmental quality ↑↑ Oceanographic Research Industrial water quality measurements	Aquaculture Data sales ↑
O3 - Optical	Offshore oil & gas Deep sea mining ↑	Monitoring of environmental quality ↑↑ Oceanographic Research Industrial water quality measurements	Aquaculture Data sales ↗
EAF - Combination	–	Monitoring of environmental quality Aquaculture ↑↑	Data sales ↗
Transversal - Antifouling	Offshore oil & gas Offshore renewable energy Deep sea mining Ocean renewable energy ↑	Monitoring of environmental quality Oceanographic Research Industrial water quality measurements ↑↑	Third-party sensor development ↗
Transversal – Interface interoperability	All markets ↑		

NeXOS innovation	Existing markets	Increase markets	New markets
Transversal – Data interoperability	Offshore oil & gas Deep sea mining	Oceano graphic Research Monitoring of environmental quality Aquaculture Industrial water quality measurements	Data sales

Follow-up actions within WP2 of NeXOS

The results presented in this deliverable (D2.3) provide the stepping stones for subsequent activities, notably the defining of business models for industrialisation (task 2.4) and the development of industrialisation strategies (task 2.5), to promote market uptake of these innovations. For tasks 2.4 and 2.5, the business strategies currently in place in relation to the product development phases identified in previous deliverables, coupled with the sources and magnitude of the added value of each NeXOS innovation for specific markets, will provide a useful toolbox to develop possible combinations of models that can be pursued.

Annex A: ASCS Progress tables per innovation

Innovation 1: A1 (WP6)

Innovation name

Compact low-power multifunctional passive acoustics sensor system, enabling on-platform measurement and characterisation of underwater noise and several soundscape sources, aimed for platforms with limited autonomy and/or communication capability.

Key success indicators

	Indicator	Measurement Unit	Current WP6-Aim	Achieved Aim	Innovation assessment	Comment
1	Size	mm*mm*mm	TBD x 36.5 diameter	255mm x 34mm diameter	**Achieved**	
2.1	Power consumption (in operation)	mWatt	Less than 1000mW	900mW @204MHz	**Achieved**	The DC/DC has been changed and now the power consumption dropped to the levels we aim
2.2	Power consumption (sleep mode)	mWatt	Less than 30mW (1 mW for analog front end and converters) + 30.8 mA CPU sleep mode + Interfaces	32mW @Sleep Mode	**On track**	
3.1	Multifunctionality 1: Embedded processing MSFD Desc 11 (Indicator 11.2.1) (Indicator 11.1.1)	# of relevant statistical features beyond minimal.	1 - Instant SPL_{rms} in 1/3 octave bands (63 and 125 Hz) re 1 uPa. 2 – Instant SPLpeak in 10Hz – 10kHz re 1 uPa. .	**1** - Instant SPL_{rms} in 1/3 octave bands (63 and 125 Hz) re 1 uPa. **2** – Instant SPL_{peak} in 10Hz – 10kHz re 1 uPa. **3**. Percentile levels (L_{10} and L_{90}) **4**. Instant SPL_{rms} in third octave bands within frequency range [22 Hz – 20 KHz] re 1 uPa **5**. Instant SPL_{rms} within user frequency range	**Achieved**	-1: D11.2.1: Certain parameters still need to be known such as hydrophone sensitivity and conversion factor of electronics. This is done on integration task. Regarding the statistical features: MSFD does not defined a standard for post-processing statistical values. It's worth to mention that post-processing is oriented to obtain annual trends. -2: D11.1.1: MSFD does not describe any procedure in order to obtain impulsive sound measurements. Solution taken is the computation of SPL_{peak} of the input signal filtered from 10 Hz to 10 kHz. The user is able to configure the algorithm's duty cycle in order to

	Indicator	Measurement Unit	Current WP6-Aim	Achieved Aim	Innovation assessment	Comment
				defined by the user re 1 uPa		obtain the results of the indicator according to his requirements. The number of relevant features are indicated with a number followed by an explanation of the feature.
3.2	Multifunctionality 2: Embedded processing MSFD Biodiversity (Desc 1)	Number of algorithms	Cover MSFD requirements (Detection) Marine mammals sound detection.	**1.** Generic mammal click detector. Detects and provides information in real time of clicks detected. SPL_{peak} and time position of the click are delivered to the user. **2.** Whistle detector Detects mammal's whistles in real time. Output consists of the number of whistles detected, and of each whistle detected will output the start and end points in time and frequency domains. **3.** Low Frequency Tonal Sound. Detects low frequency tonal sounds. Output consist of the position in time domain of the tonal sound detected.	**Achieved**	Number of algorithms are indicated with a number followed by an explanation of the algorithm **-** Whistle detector. Because of its complexity, there are problems to integrate with other algorithms in firmware.

	Indicator	Measurement Unit	Current WP6-Aim	Achieved Aim	Innovation assessment	Comment
3.3	Multifunctionality 3: Other e.g. Relevant sound samples storage etc.	# Number	1 (Sound sample storage (.wav))	1 (Sound sample storage (.wav))	**Achieved**	UPC has already implemented storage of audio data in .wav files.
4	Communication load (Transmitted)	No bits	< 60 kb (NKE profiler limit regarding data size transmission by Iridium or Rudics)	- 1: D11.2.1: SPL_{rms} and L_{10} and L_{90} value in 63 and 125 Hz: 24 Bytes - 2- 2: D11.2.1 extended: SPL_{rms} and L_{10} and L_{90} value for each third octave bands within frequency range [22 Hz – 20 KHz]: 30 bands → 360 bytes - 3: Noise band monitoring): SPL_{rms} and L_{10} and L_{90} value for a frequency range defined by the user: 12 bytes - 4: Click Detector: Peak value of click and its temporal position relative to the block of input data: 8 bytes -5 Whistle Detector: Number of whistles : 4 Bytes	**On track**	Each algorithm has its own output.
5.1	Procurement costs	€/….	Less than 5k€	Final procurement	**On track**	Final procurement cost still to be defined (industrial components

	Indicator	Measurement Unit	Current WP6-Aim	Achieved Aim	Innovation assessment	Comment
	(CAPEX)			cost to be defined based on the scale of production (need more than 10 to get under 5k) TBD – It is currently 7379 €		cost in the region of 2.000 euros - Referrring to D/70 A1 version. This prize include only hardware, without firmware implementation)
5.2	Operational costs (OPEX)	€/….	Depending on mission and measurement profile	Depending on mission and measurement profile	**Focus needed (should define a sample mission)**	Depending on mission and measurement profile
6	Measurement sensitivity	db (re 1 µPa at 5 kHz)	-181	-138/158 (ch1) -178 dB (ch2)	**Above Aim**	-138/158 dB Selectable (ch1) -178 dB (ch2) (Referring to D/70 Neptune A1 version)
7	Depth	Metres	>1000m	1500	**Above Aim**	Dependent on transducer selected (D70 Neptune)
8.1	Flat frequency accuracy	(±dB)	± 3 dB	± 2 dB	**Above Aim**	Better than initial specifications
8.2	User frequency range	kHz	40kHz	50kHz	**Above Aim**	Selectable
8.3	Beam pattern	Type of beam	Omni-directional	Transducer omnidirectional	**Achieved**	At the moment – transducer is omnidirectional. Full hydro to be calibrated for achieved aim
9.	PUCK protocol communication	Yes/No	Yes	Yes	**Achieved**	
10	Data interoperability (also a list of specific standards)	# number of data and metadata standards complied with	SWE, .wav	*wav with bext chunk to record information such as timestamp or sensor sensibility, O&M*	**Focus needed**	SWE implementation pending Other standards?
11	Reliability	# number of problems identified in D3.2 resolved	All	The body is full polyurethane coating avoiding galvanic corrosion, and	**Achieved**	Identified reliability problems have been dealt with

	Indicator	Measurement Unit	Current WP6-Aim	Achieved Aim	Innovation assessment	Comment
				ensures water tightness with time EM interference resolved using spherical transducers		
12	Platforms	# number of platform types compatibility (minimum 2)	3 (glider, profiler, buoy or cable)	Progressing towards the 3 glider, profiler, buoy, auv, rov	**On track**	The extreme flexibility in terms of dimension and power consumption allow several applications in many scientific and industrial fields.
13	Technology Readiness Level – A1 (TRL)	TRL unit	TRL 8	TRL 5?	**Challenging**	Achieved aim is based on Nov 2014 data. Update needed.

Innovation 2: A2 (WP6)

Innovation name

Compact multifunctional passive acoustics sensor system, enabling real-time waveform streaming for the measurement of underwater noise and several soundscape sources, aimed for platforms with unlimited autonomy and/or communication capability.

Key success indicators

	Indicator	Measurement Unit	Current WP6-Aim	Achieved Aim	Innovation assessment	Comment
1	Size	mm*mm*mm	50x50x270	tbd	**Challenging**	Still to be defined, array structure not included
2.1	Power consumption	mWatt	-	-	**Not Applicable**	A2 is not meant for platforms with limited power
2.2	Power consumption (sleep mode)	mW	-	-	**Not Applicable**	A2 is not meant for platforms with limited power
3.1	Multifunctionality 1: Embedded processing MSFD Desc 11 (Indicator 11.2.1) (Indicator 11.1.1)	# of relevant statistical features beyond minimal	1 - Instant SPL_{rms} in 1/3 octave bands (63 and 125 Hz) re 1 uPa. 2 – Instant SPLpeak in 10Hz – 10kHz re 1 uPa.	**1** - Instant SPL_{rms} in 1/3 octave bands (63 and 125 Hz) re 1 uPa. **2** – Instant SPL_{peak} in 10Hz – 10kHz re 1 uPa.	**Focus needed**	-1: D11.2.1: Certain parameters still need to be known such as hydrophone sensitivity and conversion factor of electronics. This is done on integration task. Regarding the statistical features: MSFD does not defined a standard for post-processing statistical values. It's worth to

	Indicator	Measurement Unit	Current WP6-Aim	Achieved Aim	Innovation assessment	Comment
				3. Percentile levels (L_{10} and L_{90}) **4**. Instant SPL_{rms} in third octave bands within frequency range [22 Hz – 20 KHz] re 1 uPa **5**. Instant SPL_{rms} within user frequency range defined by the user re 1 uPa		mention that post-processing is oriented to obtain annual trends. -2: D11.1.1: MSFD does not describe any procedure in order to obtain impulsive sound measurements. Solution taken is the computation of SPL_{peak} of the input signal filtered from 10 Hz to 10 kHz. The user is able to configure the algorithm's duty cycle in order to obtain the results of the indicator according to his requirements. The number of relevant features are indicated with a number followed by an explanation of the feature.
3.2	Multifunctionality 2: Embedded processing MSFD Biodiversity (Desc 1)	Number of algorithms.	Cover MSFD requirements (Detection) Marine mammals sound detection.	**1.** Generic mammal click detector. Detects and provides information in real time of clicks detected. SPL_{peak} and time position of the click are delivered to the user. **2.** Whistle detector Detects mammal's whistles in real time. Output consists of the number of whistles detected, and of each whistle detected will output the start and end points in time and frequency	**Achieved**.	Number of algorithms are indicated with a number followed by an explanation of the algorithm **-** Whistle detector. Because of its complexity, there are problems to integrate with other algorithms in firmware.

	Indicator	Measurement Unit	Current WP6-Aim	Achieved Aim	Innovation assessment	Comment
				domains. **3.** Low Frequency Tonal Sound. Detects low frequency tonal sounds. Output consist of the position in time domain of the tonal sound detected.		
3.3	Multifunctionality 3: Other e.g. Relevant sound samples storage, etc.	# Number	1 (Sound sample storage (.wav))	1 (Sound sample storage (.wav))	**Achieved**	UPC has already implemented storage of audio data in .wav files.
3.4	Tracking algorithm	# Number of algorithms developed.	Impulsive sound and biodiversity vocalization	**1.** Detection and Tracking of acoustic sources.	**Achieved**	Already implemented in Python on A2 Master (Odroid C2). Tests carried out so far are inconclusive. A real A2 sensor is needed.
4	Communication load (Transmitted)	No bits	In principle, there are no restrictions.	- 1: D11.2.1: SPL value in 63 and 125 Hz: 16 bits + 16 bits. - 2: Click Detector: Peak value of click and its temporal position relative to the block of input data: 16 bits + 16 bits.	**Achieved**	Features include MSFD noise statistics and bioacoustic detection.
5.1	Procurement costs (CAPEX)	€/….	-	Final procurement cost to be defined based on the scale of production. It is currently 44600 €	**On track**	Including four A2hyd, master unit, PATCH ethernet cable
5.	Operational costs (OPEX)	€/….	Depending on mission and	Depending on mission and	**Focus needed**	Depending on mission and measurement profile

	Indicator	Measurement Unit	Current WP6-Aim	Achieved Aim	Innovation assessment	Comment
2			measurement profile	measurement profile	**(should define a sample mission)**	
6	Measurement sensitivity	dB (re 1 µPa at 5 kHz)	- 181	-141/161 (ch1) -181 dB (ch2)	**Above Aim**	For deep water application only - 181 not is sufficient will be the possibility to select hi or low gain via software (referred to JS-B100 by JandS)
7	Depth	Metres	3.000+	JS-B100 @ 3600m	**Achieved**	Dependent on hydrophone selected (JS B100)
8.1	Sensitivity Accuracy	(±dB)	±3	±1,5	**Above Aim**	Dependent on hydrophone selected (JS B100)
8.2	User frequency rate	kHz	40	50	**Above Aim**	Dependent on sampling rate
8.3	Beam pattern	Type of beam	Omni-directional	Omni-directional	**Achieved**	
9.	PUCK protocol communication	Yes/No	Yes	Yes	**Achieved**	
10	Data interoperability (also a list of specific standards)	# number of data and metadata standards complied with	SWE (list of other standards aimed)	SOS Transactional operations, O&M, UDP streaming.	**Focus needed**	
11	Reliability	# number of problems identified in D3.2 resolved	Deal with identified reliability problems	No problems have been identified yet	**On track**	Assuming no problems identified
12	Platforms	# number of platform types compatibility	Several: Buoys, cables, ships	All achieved	**Achieved**	
13	Ancillary variables (Compass, CTD)	Yes/no	Yes	Yes	**Achieved**	The system for the processing need of a absolute positioning unit (Pan Tilt Compass) depth and Sound Velocity Profiler SVP.
14	Technology Readiness Level – A2 (TRL)	TRL unit	TRL 8	TRL 5 ?	**Challenging**	Achieved aim is based on Nov 2014 data. Update needed.

Innovation 3: O1 (WP5)

Innovation name

Compact low-power multifunctional optical sensor system based on multi-wavelength fluorescent technology to provide detailed information on both water constituents and other relevant contaminants being optically active in the respective spectral region.

Key success indicators

	Indicator	Measurement Unit	Current WP5-Aim	Achieved Aim	Innovation assessment	Comment
1	Size	mm*mm	200 * 50 (Diameter)	Length: 153 (without connector), 195 (with conn) Dia: 36	**Above target**	There is no size proposed in the document: There is already a mechanical interface called puck size port Diameter is 60.3 mm max length 80 mm (Alseamar can provide more information)
2	Power consumption	mWatt (at 12V)	<3,000	2,500	**Above target**	
3	Multifunctionality	Number of parameters	coloured dissolved organic matter (CDOM)/ Chlorophyll-a/ phycocyanin PAH/ NN (BTX)	All four parameters integrated (see comment), testing is shifted to Aug/Sep 2016	**On Track**	Two versions of the system with different wave length combinations: VIS (visible light) for CDOM/ chlorophyll/ phycocyanin/turbidity, UV (ultraviolet light) for CDOM/ PAHs/NN
4.1	Communication features	Yes/No	Digital communication modes with SensorWeb-communication system	Modes supported	**Achieved**	Current firmware version is working properly, but due to laboratory results under continuous development
4.2	Data interoperability	3	*MODBUS/ OGC PUCK/ SensorML*	MODBUS, OGC Puck and SensorML are supported	**Achieved**	Connection to SOS due to SensorML was successfully shown on OI 2016, London
5.1	CAPEX	€	10,000	Not certain yet, potentially UV: 13000,- VIS: 5000,-	**On-Track**	Still prototype product version in lab-test, production line not started yet.
5.2	OPEX (without supporting unit costs)	€/year	500	Not certain yet, potentially About 700 €	**Challenging**	Cleaning +Calibration
6.1	Range (Phenantrene)	ppb	0-50 0-500	0-1000	**On-Track**	Ranges and accuracy will depend on the chosen analyte to observe. Tests could not be finished within September 2016, on going proceedings, estimated

	Indicator	Measurement Unit	Current WP5-Aim	Achieved Aim	Innovation assessment	Comment
						final version withi October/November 2016
6.2	Range (Tryptophan-like)	ppb	0-200	0-1000	**On-Track**	Idem
6.3	Range (fDOM)	ppb	0-200	0-500	**On-Track**	Idem
7.1	Accuracy (Phenantrene)	ppb	<0.2 <1.0	Still open, laboratory testing has to be run a again, second prototype version is in laboratory		Idem
7.2	Accuracy (Tryptophan-like)	ppb	<0.2	Still open		Further lab tests
7.3	Accuracy (fDOM)	ppb	<0.2	Still open		Further lab tests
8.	Time duration (response time)	cycles/second	<1 sec	<2 sec	**On-Track**	Idem
9.1	Technology Readiness Level - Minifluo (TRL)	TRL unit	TRL 7	TRL 7	**Achieved**	May 2016
9.2	Technology Readiness Level - Matrixfluo (TRL)	TRL unit	TRL 6	TRL 4	**Focus needed**	May 2016

Innovation 4: O2 (WP5) SI

Innovation name

Compact low-power multifunctional optical sensor system based on hyperspectral cavity absorption technology, enabling measurement of water constituents like dissolved organic matter, suspended matter, and phytoplankton.

Key success indicators

	Indicator	Measurement Unit	Current WP5-Aim	Achieved Aim	Innovation assessment	Comment
1	Size	cm*cm	48*13 diameter	45*6.8/13.0 diameter (this is the target which seems feasible)	**Above Aim**	Commercial product in the end of project → see presentation on General Assembly 5th OPM
2	Power consumption	Watt	Max. 10	approx. 5	**Above Aim**	Depending on the developmental status of the sensor (especially the light source), the power consumption is expected to be much lower in the end
3	Multifunctionality	3	Chlorophyll-a/ coloured dissolved organic matter (CDOM)/ Phytoplankton groups	Chlorophyll-a/ Phytoplankton group determination currently under evaluation	**On track**	CDOM to be distinguished
4.1	CAPEX	€	Max 25,000	Not certain yet, potentially < 25,000 About 23k € ?	**Focus needed**	
4.2	OPEX	€	Max 2,000	Not certain yet, potentially < 2,000	**Focus needed**	Depending on service interval due to fouling etc– Please assume maintenance is not required due to fouling as per Innovation 7 aim
5.1	Range (Absorption)	m^{-1}	0.01-10	under evaluation	**Focus needed**	
5.2	Range (Chloro)	µg/l	Calculated from the absorption coefficients, thus connected to point 5.1	under evaluation	**Focus needed**	Linear relationship between chlorophyll-a and pigment absorption established, thus detection range is linked to the detection range of absorption at the relevant wavelengths
5.3	Range (Phytoplankton groups)	Phytoplankton groups	Species/Spectral groups	7 different spectral groups	**Focus needed**	Final power of the phytoplankton identification algorithm depends on the

	Indicator	Measurement Unit	Current WP5-Aim	Achieved Aim	Innovation assessment	Comment
						number and spectra available for the reference library. Needs continuous re-evaluation. Current aim achieved is based on the currently available spectra.
6.1	Accuracy (Absorption)	%	5	under evaluation	**Focus needed**	
6.2	Accuracy (Phytoplankton groups)	Phytoplankton groups	Spectral groups	Spectral groups	**On track**	Difficult to applicate. Depending on the available spectra in the reference library for comparison; Similarity of the sample is expressed as a similarity index.
7.1	System integration	Yes/No	Dedicated link with SEISI	Not implemented	**Focus needed**	
7.2	Data interoperability	4	*MODBUS/ G2 (webbrowser)/ OGC PUCK/ SensorML*	*G2(webbrowser)*	**Focus needed**	
8	Long-term stability	# of days system can run without maintenance	14	1	**Focus needed**	
9.1	Technology Readiness Level - OSCAR (TRL)	TRL unit	TRL 5	TRL 3	**On track**	Achieved aim is based on Nov 2014 data. Update needed.
9.2	Technology Readiness Level - Flow through hyperspectral sensor (TRL)	TRL unit	TRL 6	TRL 5	**On track**	Achieved aim is based on Nov 2014 data. Update needed.

Innovation 5: O3 (WP5)

Innovation name

Compact low-power multifunctional carbon sensor system. These sensor arrays will quantify the marine carbonate system by combination of a high precision sensor for pH and AT together with a membrane based pCO2 sensor. The system includes high precision spectrophotometric pH and carbonate ion sensor with a membrane based pCO2 sensor.

NIVA,HZG and Franatech, supported by UNOL, are committed to the production of two types of array. Tentative names are Cbon2 and Cbon3. Key success indicators are described separately. Furthermore Cbon2 has two different layout, according to ferrybox deployment (Cbon2-fb) and surface vessel (Cbon2-sv)

Key success indicators: Cbon2-fb

	Indicator	Measurement Unit	Current WP5-Aim	Achieved Aim	Innovation assessment	Comment
1	Size	cm*cm*cm	pelicase box 40x50x20	designed, pelicase box 40x50x20	**Achieved**	
2.1	Power consumption (active)	supply: 220V	25W peak (during pH sampling) 15W (no pH sampling)	estimated 25W peak, real figures after first prototype ready	**On track**	Power consumption for CO2 measurements is generally high due to necessary heating of key components (notably, either for activation of a solid state sensor or avoiding condensation on optics of a NDIR set up.
2.2	Power consumption (power down)	W	No power down is planned	Ferrybox provides power continuously, independently from the sensor.	**Not Applicable**	Heating of the solid state sensor is crucial when the water is inside the extraction chamber. Residual moisture can make the sensor drifting.
3	Multifunctionality	2	pH/pCO2	Single operation mode of each parameter is working, technical aspects for combination are solved according to design	**On track**	Each single quantity is measured in a self-contained box. Aim : fitting the two schemes inside the same box.
4.1	Range (ph/pCO2)	unitless µatm	7.8 – 8.2 250-700	7.8 – 8.4 250 - 700	**Above Aim**	The pH range covering ocean acidification studies is narrow. The matter is resolving clearly seasonal changes of 0.02 and

	Indicator	Measurement Unit	Current WP5-Aim	Achieved Aim	Innovation assessment	Comment
						interannual variability down to 0.002. Lower pH detection is achieved changing the indicator and "recipe", not the device.
5.1	Accuracy (ph/pCO2)	unitless %	0.003 1%	0.005 - 0.003 to be evaluated, 2% based on previous version.	**On track**	Current indicator is optimal for pH above 8. At lower pH the detection suffer of lack of precision that eventually will extend the accuracy.
6.1	CAPEX Sensors	€	15,000 – 20,000	25,000. Note: no similar instruments exist in the market.	**Challenging**	NIVA has just evaluated the market value of the laboratory/ underway pH detection system around 12,500. The cost of fabrication is currently 5,000 manpower/3,000 hardware. NIVA and Franatech are committed to understand market potential after the first unit's performances have been evaluated.
6.2	OPEX	€/year	400	TBD? –	**Challenging**	
7	Data interoperability *(also a list of specific standards)*	2	*OGC Puck, SensorML*	Aim achieved	**Achieved**	The open platform based on Raspberry pi, the brain of the array, will support communication with the host where the data interoperability will be implemented.
8	Technology Readiness Level - Cbon2-fb (TRL)	TRL unit	TRL 7	TRL 4	**Challenging**	Need to set an aim for TRL

Key success indicators: Cbon2-sv

	Indicator	Measurement Unit	Current WP5-Aim	Achieved Aim	Innovation assessment	Comment
1	Size	cm*cm*cm	adapted to payload	designed, 30x20x14 in payload + ø10x30 through the keel	**Focus needed**	Underwater vessel is the Sailbuoy developed by CMR.
2.1	Power consumption (active)	supply: 12V	20W peak (pH sampling) 10W (no pH	designed, 15 peak estimated during pH sampling	**On track**	The array is based on same pH detection of Cbon-fb, the CO2 sensor is based on a low-power membrane/NDIR.

	Indicator	Measurement Unit	Current WP5-Aim	Achieved Aim	Innovation assessment	Comment
			sampling)			
2.2	Power consumption (power down)	W	Some power saving options are considered.	Separate power management from host navigation computer	**Focus needed**	Heating of the NDIR is crucial. Residual moisture can make the sensor drifting and condensation on the optics occour.
3	Multifunctionality	2	pH/pCO2	The array consists of a spectrophotometric pH detection layout and an underwater CO2 sensor plugged through the keel of the vesse	**Achieved**	According to DoW, this is met. The two sensing systems work closely and interact with a control unit, integrated in the same platform.
4.1	Range (ph/pCO2)	unitless µatm	7.8 – 8.2 250-700	7.8 – 8.4 250 - 700	**Above Aim**	The pH range covering ocean acidification studies is narrow. The matter is resolving clearly seasonal changes of 0.02 and interannual variability down to 0.002. Lower pH detection is achieved changing the indicator and “recipe”, not the device.
5.1	Accuracy (ph/pCO2)	unitless %	0.003 2%	0.005- 0.003 to be evaluated 3% according to previous versions.	**On track**	Current indicator is optimal for pH above 8. At lower pH the detection suffer of lack of precision that eventually will extend the accuracy. pCO2 detector needs evaluation in situ, due to water turbulence effects.
6.1	CAPEX Sensors	€	15,000 – 20,000	TBD	**Challenging**	The fabrication is strictly payload/platform dependent. Difficult to estimate. It is thought as a “service” rather than a “product”.
6.2	OPEX	€/year	400	TBD? –	**Challenging**	
7	Data interoperability *(also a list of specific standards)*	2	*OGC Puck, SensorML*		**Focus needed**	The open platform based on Raspberry pi, the brain of the array, will support communication with the host where the data interoperability will be implemented.
8	Technology Readiness Level - Cbon2-sv (TRL)	TRL unit	TRL 7	TRL 4	**Challenging**	Need to set an aim for TRL

Key success indicators: Cbon3-fb

	Indicator	Measurement Unit	Current WP5-Aim	Achieved Aim	Innovation assessment	Comment
1	Size	mm*cm*cm	pelicase box 400x500x200 + chassis 480x400x320	designed, pelicase box 40x50x20	**Challenging**	External expansion with a chassis for alkalinity (TA) measurement.
2.1	Power consumption (active)	supply: 220V	70 peak	75, estimated	**Focus needed**	Power consumption for TA measurement exceeds power consumption for pH/pCO2 (Cbon2-fb). Temperature stability for the titration process is mandatory to preserve accuracy.
2.2	Power consumption (power down)	W	No power down is planned	Ferrybox provides power continuously, independently from the sensor.	**Not Applicable**	Heating of the solid state sensor is crucial when the water is inside the extraction chamber. Residual moisture can make the sensor drifting. Power consumption for TA measurement exceeds power consumption for pH/pCO2 (Cbon2-fb). Temperature stability for the titration process is mandatory to preserve accuracy.
3	Multifunctionality	3	pH/pCO2/TA	Single operation mode of each parameter is working, combining is designed and fabrication started.	**On track**	Each single quantity is measured in a self-contained box. The aim is providing the Cbon2-fb aside the TA box coordinated by a single control unit capable to deliver an array of data.
4.1	Range (ph/pCO2/TA)	unitless µatm µmol/kg	7.8 – 8.2 250-700 2000 – 2400	7.8 – 8.4 250 – 700 2000 - 2400	**Above Aim**	The pH range covering ocean acidification studies is narrow. The matter is resolving clearly seasonal changes of 0.02 and interannual variability down to 0.002. Lower pH detection is achieved changing the indicator and “recipe”, not the device.
5.1	Accuracy (ph/pCO2)	unitless % 	0.003 1% 0.5%	0.005- 0.003 to be evaluated 1%	**On track**	Current indicator is optimal for pH above 8. At lower pH the detection suffer

	Indicator	Measurement Unit	Current WP5-Aim	Achieved Aim	Innovation assessment	Comment
						of lack of precision that eventually will extend the accuracy.
6.1	CAPEX Sensors	€	TBD – Is it like 15,000 – 20,000?	TBD	**Challenging**	The fabrication is strictly ferrybox dependent. Difficult to estimate. It is thought as a "service" rather than a "product".
6.2	OPEX	€/year	400	TBD	**Challenging**	
7	Data interoperability *(also a list of specific standards)*	2	OGC Puck, SensorML	Has any of the standards been achieved?	**Focus needed**	The open platform based on Raspberry pi, the brain of the array, will support communication with the host where the data interoperability will be implemented.
8	Technology Readiness Level - Cbon3-fb (TRL)	TRL unit	TRL 7	TRL 4	**Challenging**	Need to set an aim for TRL

Innovation 6: EAF (WP7)

Innovation name

Low-cost, high autonomy, small and steady chlorophyll and oxygen sensors for fishing vessels for an Ecosystem Approach to Fisheries (EAF) management. The new sensors will complement the measurement of fish catch, fishing activity tracking, temperature and salinity.

Key success indicators

	Indicator	Measurement Unit	Current WP7-Aim	Achieved Aim	Innovation assessment	Comment
1	Size	mm*mm*mm	Dia 60 * 300	Dia 40 * 250	**Above Aim**	At the present time NKE T/P recorders are 171mm *27 mm and NKE CTD recorders are 217mm * 30mm New sensors should not be much bigger because they have to be designed in order to have the lesser impact possible on the fishing activity
2	Measured parameters	Yes/No	Oxygen/ chlorophyll/ depth/ temperature/ salinity	Oxygen / Temp/ Depth – Fluo done	**Achieved**	Are we still lacking salinity and chlorophyll?? Salinity already exist even before Nexos ! Fluo is Chlorophyll ! And the sensor has been developed nearly at the same time than O2. There are the two sensors developed by Nexos
3.1	Range (O2)	mg/L	0 to 100 %	0 to 100%	**Above Aim**	
3.2	Range (chlorophyll)	FFU or ug/L chla	0 to 500 FFU	0 to 500 µg/L	**Achieved**	Turner Cyclops
4.1	Accuracy (O2)	%Saturated Air, µmol/L or mg/L	<5%	Under evaluation Actually, environment and metrology testing is running (june 2016)	**Focus needed**	Limit of detection is known : 0,02 % (0.01 mg/L)
4.2	Accuracy (chlorophyll)	FFU or ug/L chla	+/- 0.025 µg/l	Under evaluation Actually, environment and metrology	**Focus needed**	Limit of detection is known : 0.025 µg/L

	Indicator	Measurement Unit	Current WP7-Aim	Achieved Aim	Innovation assessment	Comment
				testing is running (june 2016)		
5	Operating Depth	M	600	300m for both sensors	**Focus needed**	Probably is better to have various versions e.g. 300m , 600m
6	Operating temperature range	ºC	-20 °C to 50°C	5°C to 35°C for DO -5°C to 35°C for Fluo	**Focus needed**	Is this Aim realistic? Is such a arrange in temperatures needed? Current WP7 Aim is not realistic. The one given in the achieved aim is OK
7	Battery duration	Months	6	Under evaluation	**Focus needed**	Depending on the measurement rates and the immersion time of sensors (according to fishing gears) – Assuming an average situation. What is the measurement rate and immersion time considered when aiming for 6 months duration? Need to ask NKE
8	Memory storage capacity	Months (with 1 meas/min)	6	Under evaluation	**Focus needed**	Depending on the measurement rates and the immersion time of sensors (according to fishing gears) - Assuming an average situation. What is the measurement rate and immersion time considered when aiming for 6 months duration? Need to ask NKE
9	Sensor response time	Sec	DO: < 30 s and < 10 s at 63 % Chlorophyll: < 30 s and < 3 s at 63 %	DO : 10 seconds at 63% Fluo : <1 s	**Focus needed**	The response time of DO and Fluorescence sensor will be evaluated at IFREMER laboratory. Work in Progress (June 2016)
10.1	System CAPEX	€/ RECOPESCA system	<6000 € - Does this aim refer to the whole RECOPESCA	Chl-a: The targeted price is 5300€ (without	**Focus needed**	Sonde including datalogger + sensors T, P, O_2 or Chl-a + communication. A RECOPESCA sonde

	Indicator	Measurement Unit	Current WP7-Aim	Achieved Aim	Innovation assessment	Comment
			system? NO	VAT) DO : The targeted price is 5300€ (without VAT)		requires 2 or 3 sensing elements integrated into a waterproof housing, autonomous, capable to store and transmit data by radio to concentrator. What do you mean, per sensor? Or the whole system RECOPESCA? If you mean per sensor, it will depend on the operative range and on how many you buy according to my previous experience with NKE probes (1000-3000 €) Of course the less it costs the higher number of boats can be equipped in a monitoring system.
10.2	System OPEX	€/year	< 500€ / year	Under evaluation	**Focus needed**	This implies the cost for changing batteries, sensing foil calibration of instruments? **Yes** Calibration costs should be determined and added.
11	Robustness	How is this measurerd? Should be evaluated according to Blas Galvan (Plocan) methodology	TBD	Under evaluation at Ifremer (NFX10-812 standards)	**Focus needed**	They have to be confirmed on fishing gears in order to determine robustness. - **Is this part of a demonstration?**
12	Drift	mg/l (O2) FTU (fluo)	TBD	Under evaluation at Ifremer (NFX10-812 standards) Work in progress (June 16)	**Focus needed**	They have to be deployed on fishing gears in order to determine drift after several months. - **Is this part of a demonstration?**
13	Data interoperability *(also a list of specific standards)*	# number of data and metadata standards complied with	(list of standards aimed) – Please Define	(list of standards supported)	**Focus needed**	RECOPESCA is an existing proprietary system (since 2005) – Does this mean we only aim for interoperability with RECOPESCA? Has

	Indicator	Measurement Unit	Current WP7-Aim	Achieved Aim	Innovation assessment	Comment
						this been achieved? I think data are available on international portal : Coriolis
14.1	Technology Readiness Level - EAF temperature/dissolved oxygen (TRL)	TRL unit	TRL 7	TRL 3? Surely not TRL 3, much more, I would presume TRL6	**Challenging**	Need to set an aim for TRL
14.2	Technology Readiness Level - EAF temperature/fluorescence (TRL)	TRL unit	TRL 7	TRL 3? Surely not TRL 3, much more, I would presume TRL6	**Challenging**	Achieved aim is based on Nov 2014 data. Update needed.

Innovation 7: Antifouling (WP3)

Innovation name

An innovative scheme using active protection is proposed, controlling biocide generation with a biofilm sensor. This will have high efficiency for optical sensors, low power consumption and negligible environmental impact. The scheme will involve the application of a conductive coating on the transducing interfaces of the sensors. This coating will allow micro-surface-electrolysis, and very little biocide will be produced over the entire sensor.

Key success indicators

SnO_2 optical windows protection scheme

	Indicator	Measurement Unit	Current WP3-Aim	Achieved Aim	Innovation assessment	Comment
1	Size	cm*cm*cm	Integrated to existing sensor. So, should conduct to no variation of the original size of the sensor	Integrated to the sensor used for test. Design still in development (c.f. Deliverable 3.3).	**On track**	
2	Power consumption	mWatt	10 mWatt	10 mWatt	**Achieved**	
3	Sensor maintenance costs due to fouling	€/year	Maintenance should not be necessary due to fouling (this is	13 months protection achieved. 24 months	**Focus needed**	

	Indicator	Measurement Unit	Current WP3-Aim	Achieved Aim	Innovation assessment	Comment
	(OPEX)		the goal). it's achieved if a 36 months protection is obtained.	coating duration is achieved (2016 update)		
4	Antifouling duration	months	36 months	13 months 24 months coating duration is achieved (2016 update)	**Focus needed**	
5	CAPEX	€	200 – how has this been defined? Because this what it cost up to now when the coating is done one by one… so, it can't be more expensive ;-)	Still under evaluation. And since protection should be integrated to the sensor, it's part of it's design and part of the global cost of the sensor…	**Focus needed**	To lower the cost, the sensor manufacturer should investigate the adaptation. – What is the current adaptation cost for each of the sensors? Very difficult to evaluate, since the adaptation to existing sensor is not the way to do it. It should be integrated from scratch design.
6	Technology Readiness Level - SnO_2 antifouling (TRL)	TRL unit	TRL 7	TRL 6	**Challenging**	Achieved aim is based on Nov 2014 data. Update needed. Update complete

Biofilm sensor

	Indicator	Measurement Unit	Current WP3-Aim	Achieved Aim	Innovation assessment	Comment
1	Size	cm*cm*cm	Dia 6, Length 12.5 ? For glider and AUV the sensor can be adapted, basing on specific needs (that were not indicated at the begin of the Task and currently are still unknown)	Dia 12, Length 25	**Focus needed**	
2	Power consumption	mWatt	Would 50 mWatt be acceptable/ achievable?	max 33 mW (0.33 mW during sleep)	---	
3	Sensor	€/year	Maintenance	Experiment not	**Focus**	

	Indicator	Measurement Unit	Current WP3-Aim	Achieved Aim	Innovation assessment	Comment
	maintenance costs due to fouling (OPEX)		should not be necessary due to fouling (this is the goal). it's achieved if a 36 months protection is obtained.	done - When is this conducted? Results? Lab test ok In situ test done now ! Result in October 2016	**needed**	
4	Antifouling duration	Months	36 months	Experiment not done - When is this conducted? Results? The biofilm sensor should not have this aim. This the protected sensor that has this aim.	**Focus needed**	
5	CAPEX	€	tbd.- Let's make a sample case It depends on a lot of configuration of use (subsea obs, glider, AUV…)	TBD – The current price for fixed station is about 7K€ (calculated for the production of the prototypes). For glider and AUV the sensor can be adapted, basing on specific needs, that will determine the exact price. Price subject to reduction in case of industrial production.	**Focus needed**	To lower the cost, the adaptation should be investigated by the sensor manufacturer. – Can we define a sample of costs for different use configurations? (for a glider/ AUV etc.) Can we use the demonstration configurations as examples? I doubt the biofilm sensor in its actual size is ready fro deployement for AUV/Glider The price for fixe station should be known, since it's a product from ALVIM company. Should be asked to Giovanni
6	Technology Readiness Level - Biofilm monitoring (TRL)	TRL unit	TRL 7	TRL 6 determination in progress	**Challenging**	Achieved aim is based on Nov 2014 data. Update needed.

SnO_2 optical windows protection scheme + Biofilm sensor

	Indicator	Measurement Unit	Current WP3-Aim	Achieved Aim	Innovation assessment	Comment
1	Size	cm*cm*cm	Dia 6, Length 12.5 ?	Diam 12, Length 25 + internal to sensor	**Focus needed**	Size is not relevant for the combine scheme
2	Power consumption	mWatt	Would 50+6mWatt be acceptable/ achievable?	10 mWatt + max 33 mW (0.33 mW during sleep)	---	yes
3	Sensor maintenance costs due to fouling (OPEX)	€/year	Maintenance should not be necessary due to fouling (this is the goal). it's achieved if a 36 months protection is obtained.	Experiment not done - When is this conducted? Results? Still in progress, 36 months duration	**Focus needed**	Identical to SnO2 antifouling !
4	Antifouling duration	Days	36 months	Experiment not done - When is this conducted? Results? Still in progress, 36 months duration	**Focus needed**	
5	CAPEX	€	tbd.- Let's make a sample case It depends on a lot of configuration of use (subsea obs, glider, AUV…)	TBD – For biofilm sensor: The current price for fixed station is about 7K€ (calculated for the production of the prototypes). For glider and AUV the sensor can be adapted, basing on specific needs, that will determine the exact price. Price subject to reduction in case of industrial production.	**Focus needed**	To lower the cost, the adaptation should be investigated by the sensor manufacturer. – Can we define a sample of costs for different use configurations? (for a glider/ AUV etc.) Can we use the demonstration configurations as examples?
6	Technology	TRL unit	TRL 7	TRL 2?	**Challenging**	Is this the right table for the

	Indicator	Measurement Unit	Current WP3-Aim	Achieved Aim	Innovation assessment	Comment
	Readiness Level - Biofouling protection control system (TRL)			In situ test in progress (june 2016) So, TRL 6 is targeted		Biofoullng protection control system TRL? Achieved aim is based on Nov 2014 data. Update needed.

Innovation 8: Interface interoperability (WP4)

Innovation name

The Smart Electronic Interface for Sensor Interoperability (SEISI) will provide a multifunctional interface for many types of current sensors and instruments, as well as for the new multifunctional detectors to be developed by WP5, 6, and 7.

Key success indicators

	Indicator	Measurement Unit	Current WP4-Aim	Achieved Aim	Innovation assessment	Comment
1.1	Multifunctionality	#of enabled hardware systems	Optical systems/.Passive acoustic monitoring system/etc.	Optical systems O1 Passive acoustic systems A1 and A2	**On track**	
1.2	Multifunctionality	#of NeXOS interfaces tested	For all NeXOS scenarios	Laboratory tests with Optical systems (O1) and Passive acoustic system (A1/A2) have been done. Also some sensor-platforms tests have been started with this two systems form some of the NeXOS scenarios	**On track**	When are tests taking place?
2	Power consumption	Yes/No	Power and modular design with variable frequency clocks	**Yes**	**Achieved**	
3.1	Sensor interfaces	Yes/No	Implementation of OGC-PUCK protocol	Provide a standard mechanism to identify any PUCK Enabled Instrument	**Achieved**	
3.2	Sensor interfaces	Yes/No	Implementation of PTP	For Ethernet instruments, provide a standard mechanism to synchronize time clock	**Achieved**	
3.3	Sensor interfaces	Yes/No	Open Source software development tools	Open source software is used	**Achieved**	
4.1	Cost	#of observing platforms the sensor is adaptable to	The majority of the observing platforms (%): CMR Sail Buoy, Teledyne Webresearch Slocum Glidder, Cabled Observatories like Obsea	1. Platforms with low/medium power supply and satellite link (e.g. ARGO profiling floats, underwater gliders, AUVs). Sensors adapted: O1 and A1 2. Platforms with low/medium power	**On track**	

	Indicator	Measurement Unit	Current WP4-Aim	Achieved Aim	Innovation assessment	Comment
				supply and no data transmission (deep sea observatories). Sensors adapted: O1 and A1 3. Platforms with medium power supply and Freewave, Wi-Fi link, GSM link (Moored buoys near the coast, Voluntary Observing Ship VOS, Scientific vessels). Sensors adapted: All (with some configurations changes) 4. Platforms with high power supply and cable link (Underwater cabled observatories). Sensors adapted: All		
4.2	Cost	Yes/No	Make sensor systems modular and reconfigurable	Yes	**Achieved**	
4.3	Cost	Yes/No	Has a reduction in sensor size for integration on small mobile platforms been facilitated?	Yes	**Achieved**	
4.4	Cost	Yes/No	Has the implemention of remote control and reconfiguration of sensors and monitoring strategies been enabled	Yes	**Achieved**	
5.1	Reliability	Yes/No	Has the traceability of sensor data increased?	Yes	**Achieved**	
5.2	Reliability	Yes/No	Can SEISI be implemented in a	Yes	**Achieved**	

	Indicator	Measurement Unit	Current WP4-Aim	Achieved Aim	Innovation assessment	Comment
			robust fashion meaning that it enhances reliability instead of adding risks?			
6.1	Compatibility	Yes/No	Is SEISI compatible with existing, commercially available sensor systems or are there certain constraints on the implementation?	Yes	**Achieved**	
6.2	Compatibility		Does SEISI provide adequate information to describe the sensor functionalities? yes	Yes	**Achieved**	
7	Sensor Web Integration	Yes/No	Has a link between the SESI and SWE been established in an efficient manner?	Yes	**Achieved**	
8	Technology Readiness Level - SEISI (TRL)	TRL unit	TRL 8	TRL 4	**On track**	

Innovation 9: Data interoperability (WP4)

Innovation name

A Sensor Web architecture (WP4) will be developed utilizing relevant standards and best practices for the NeXOS sensors. Suitable Web services and tools conforming to those standards will be implemented and packaged as a toolbox for the deployment in different ocean observing systems.

Key success indicators

	Indicator	Measurement Unit	Current WP4-Aim	Achieved Aim	Innovation assessment	Comment
1	Multifunctionality	#of enabled sensor data sources	Optical systems/. Recopesca systems/etc.	Up to now: Stations of UPC and PLOCAN are Sensor Web Enabled. Furthermore, a test system of TriOS (WP5) has been coupled with the Sensor Web components (SOS). Also Ferrybox data from HZG has been successfully added to the Sensor Web infrastructure.	**On track**	
2.1	Web enablement	Yes/No	Implementation of OGC IT standards (SWE)	Yes, up to now: Implementations of SOS, SPS, SES and Sensor Web Client are available. Significant enhancements are completed (e.g. support of mobile sensors). In addition new standards such as the OGC Pub/Sub specification are currently in the evaluaton.	**On track**	
2.2	Web	Yes/No	Facilitation of	Yes, different	**Achieved**	

	Indicator	Measurement Unit	Current WP4-Aim	Achieved Aim	Innovation assessment	Comment
	enablement		the integration of sensors with SWE components	options to connect sensors and sensor databases with SWE are available: Hibernate Layer for the SOS, SOS Importer		
3	Cost	Yes/No	Has an efficient communication approach been established to minimize communication costs?	More efficient protocols such as EXI in conjunction with the SOS ResultHandling operations have been implemented.	**Achieved**	
4	Reliability	Yes/No	Has the traceability of sensor data increased?	A profile of SensorML 2.0 for NeXOS has been developed. This is already a first improvement to better describe the process through which sensor data sets were generated. This profile has also been incorporated into the SOS implementation of 52°North. Finally, a first full version of a SensorML editor supporting this profiles is available.	**Achieved**	
5	Community Building	Number of new users of and contributors to the developed open source components	Increase the number of users of and contributors to the developed SWE components.	Up to now. First additional users or contributors have joined the 52N community. Furthermore, there is interest	**On track**	

	Indicator	Measurement Unit	Current WP4-Aim	Achieved Aim	Innovation assessment	Comment
			Convince further project to contribute to the NeXOS developments.	by other projects (COMMON SENSE) to use and contribute to NeXOS developments. The 52°North Sensor Web Workshop 2015 (November 2015) and the 52°North Sensor Web Conference 2016 (August 2016) were further steps to showcase some of the NeXOS developments. Further events include a demonstration at the Oceanology International and presentations at conferences such as FOSS4G 2016 and the INSPIRE Conference 2016. Finally, there are ongoing efforts to cooperate with other projects to develop a common marine SWE profile to increase interoperability between different projects.		

	Indicator	Measurement Unit	Current WP4-Aim	Achieved Aim	Innovation assessment	Comment
6	Documentation	Yes/No	Has a best practice document on how to apply SWE in Oceanography been published	This work has been initiated. A wiki is in place in which usage examples of SWE standards were collected. Based on this, the outline of a marine SWE profile and best practice is currently being developed.	**On track**	
7	Compatibility		Is the developed system compatible to the GEOSS information system (registration, standards etc)?	The SOS can already be linked to the GEOSS Common Infrastructure as there is a SOS adapter for the GEOSS Discovery and Access Broker.	**Achieved**	
8	Scalability		Is the suggested architecture scalable to larger sensor networks?	Yes, the SOS implementation is capable of handling large sensor networks comprising thousands of sensors. The data loading mechanisms will be investigated during the remaining time of the project.	**Achieved**	
9	Technology Readiness Level - Marine Sensor web architecture (TRL)	TRL unit	TRL 7	TRL 6/TRL 7 (depending on the component: SOS, HELGOLAND can now be considered as TRL 7).	**On track**	