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# *Copernicus ex- ante benefits assessment*

December, 1<sup>st</sup> 2017

## Executive Summary

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# ***1 Context of the study***

## ***1.1 Introduction***

This document is a summary of the full report named: “Copernicus Ex-Ante benefits assessment”. It aims at conveying the main findings and results of the original report. Therefore, only figures and the most important analyses have been extracted from the full report, in order to provide the reader with critical insight on the different existing and expected impacts that the Copernicus programme has on the European society and economy. For concision reasons, impact pathways and some of the benefits being assessed only qualitatively, have not been presented in this summary. For more details, the reader should refer to the complete report.

## ***1.2 Objectives of the study***

The objective of the study was to carry out an impact assessment in support of the future European Commission Impact Assessment (IA) on the evolution of the Copernicus programme. This IA analysed three potential options for the evolution of the Copernicus programme, comparing them to a baseline option which ensures the continuity of the Copernicus programme as is (i.e. with unchanged scope). The options under scrutiny are detailed in the next section 2. Options characterisation.

The present study focuses on the assessment of Copernicus Data and information (D&I) spillovers benefits, meaning the impacts on the wider European society of the utilisation and exploitation of Copernicus D&I. The benefits are considered for the intermediate and end-users market. The scope of the impact assessment covers economic, societal and environmental benefits valuation, for Europe only, and for a period of time covering the 2017 - 2035 period.

The ultimate goal was to give a monetary value to all the benefits (as much as possible) generated by the Copernicus programme over the period 2017 - 2035, in order to provide the EU and national policy makers, with an estimate of the potential return on investment.

## ***1.3 The Copernicus Programme***

The Copernicus programme is one of the European flagship programme providing free and open data and information relying on satellite-based imagery, models and in-situ data. More than only data and information, the Copernicus programme provides state-of-the-art models to be used for societal and environmental purposes. The Copernicus programme is a public service designed to respond to policy and public administrations and foster economic growth in Europe by:

- Supporting public users at local, national and European level;
- Helping Europe to maintain a prominent role in the international context;
- Strengthening intermediate users, downstream companies and value-added service providers.

Even if the programme is considered as an Earth Observation programme, the content of its offering must not be reduced to satellite-based imagery only as it also provides a free and open access to many information products develop by its six core services as well as to many sources of in-situ data provided by European Union Member’ States (EU MS). Therefore the programme architecture is based on three components: the Space component, the In-situ component and the Services component.

The Copernicus services component aims to deliver data and products freely available for a wide variety of users. The products offered integrate data from the Space and In-situ components, together with state-of-the-art models. To better reach end-users, six different core services were developed or are currently being developed in different areas:

- Copernicus Land Monitoring Service (CLMS);
- Copernicus Marine Environment Monitoring Service (CMEMS);
- Copernicus Atmosphere Monitoring Service (CAMS);
- Copernicus Climate Change Services (C3S);

- Copernicus Emergency Management Service (EMS);
- Copernicus Security Service (CSS).

Copernicus D&I can contribute to the development of advanced information products, such as Geographic Information Systems (GIS). Nowadays Earth Observation data are mixed with other type of data (in-situ, social media, historical statistics, etc.) thanks to powerful computing and analytics intelligence to develop advanced geospatial products. The Copernicus programme can feed these new trends by providing data and information openly and freely on its platform (raw or semi-raw data), but can also offer already processed information products through its core services (value added maps, reporting, modelling...). Hence Copernicus targets both value-added software/application developers (intermediate users) and final users consuming finalized products based on processed Copernicus EO and In-Situ data (end-users, either public or private).

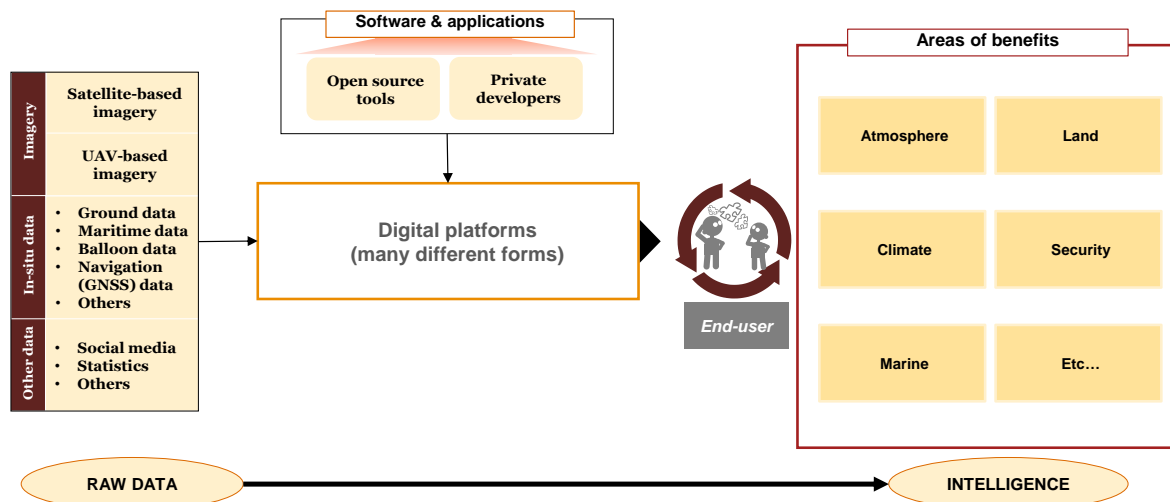


Figure 1 - Illustration of the information product value-chain (Sources: PwC analysis)

The present study assesses the impacts of the intelligence created by the Copernicus programme in its current scope and in potential evolution options on the European society. The study specifically examines the value created and offered to end-users, with particular focus on environmental and societal benefits, thanks to the Copernicus information products value-chain. As mentioned earlier, this study only focuses on the impacts of the utilisation and exploitation of Copernicus D&I, leaving aside impacts on and from the upstream side of the value chain (impacts on and from satellite and ground segment development and manufacturing industry).

## 2 Options characterisation

This impact assessment delves into four different options. Three of them are potential evolution options and one is the baseline scenario, serving as a reference point of comparison for the analysis. The thematic of the different options to be analysed have been provided by the European Commission.

Each option has a specific scope, leading to different types of benefits: Option 1 is “Continue the Copernicus programme”, option 2 is the shutdown of Copernicus and implies the non-renewal of space assets after 2030, option 3 and 4 comprise enhanced services dedicated to environment and security, respectively.

The baseline option (option 1) was characterised with an ex-ante assessment of its expected evolution up to 2035, in order to assess how the current scope of Copernicus would evolve in case of no additional or extended services.

Option 2 is mutually exclusive from the other evolution options, whereas options 3 and 4 are not mutually exclusive. As stated in the table below, option 3 is modular and each of the four modules can be developed separately together, or not, with option 4.

The following table gives additional details on each option.

	Description
<b>Option 1</b> <i>(baseline option)</i>	Option 1 continues the Copernicus programme and represents the baseline option: <ul style="list-style-type: none"> <li>• Continue Copernicus services, including an incremental improvement of the data and service foreseen as results of technology progresses</li> <li>• Renew Sentinels fleet</li> </ul>
<b>Option 2</b>	Option 2 stops the Copernicus programme: <ul style="list-style-type: none"> <li>• No renewable of assets</li> <li>• Transfer of ownership of satellites</li> <li>• Stop and disassemble services</li> </ul>
<b>Option 3</b>	Option 3 continues the Copernicus programme and expands environmental capabilities with the following services: <ul style="list-style-type: none"> <li>• Option 3A – Anthropogenic CO<sub>2</sub> emissions monitoring;</li> <li>• Option 3B – Arctic (polar, snow &amp; ice) environment monitoring;</li> <li>• Option 3C – Additional thermal infrared capability;</li> <li>• Option 3D – Additional hyperspectral capability</li> </ul>
<b>Option 4</b>	Option 4 continues the Copernicus programme and expands security capabilities with the following services: <ul style="list-style-type: none"> <li>• Access to VHR imagery (satellites and/or UAVs) for security applications</li> <li>• Access to near-real time monitoring capability for security applications</li> <li>• Guaranteed access for security applications</li> </ul>

*Table 1 - Options under scrutiny (Source: EC)*

The four options are further detailed in the sections dedicated to the baseline assessment and to the evolution options.

## 3 Impact Assessment Approach

### 3.1 Methodology

The methodology developed for this impact assessment relies on four steps detailed below. Phases 1 and 2 deal with the characterization of the different options and the scope definition in order to identify the impacts that must be included in (significant and assessable) or excluded from the scope of this study. Phase 3 and 4 focus more on the high level quantification process used to assess and monetize Copernicus D&I spillovers, meaning all benefits derived from Copernicus D&I for intermediate and end-users.

It is worth pointing out that the methodologies are tied to specific impact categories (with different impacts requiring different assessment methodologies): therefore, for the purpose of clarity, the detailed methodological approach is presented directly in the description of each impact (see “Impact Assessment section”).

The four main steps conducted for the execution of this impact assessment are the following:

- **Phase 1 – Options characterisation.** As mentioned above, each individual option was characterised, with a particular focus on the baseline option (option 1) representing the current scope of the Copernicus programme, including renewable of Sentinels fleet. The description, characterisation and scope (potential number of satellites, launch date anticipated, etc.) of each option were provided by the European Commission;
- **Phase 2 – Identification of the impact drivers and their derived benefits (impacts).** Firstly an extensive list of all potential applications of Copernicus D&I was developed through a combination of internal knowledge, past assessment work and desk research. The initial list of applications was

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complemented and calibrated through stakeholder consultation with experts from the EC and Copernicus core services. In the rest of the study, Copernicus' applications are called "Impact drivers" to highlight the fact that they are examples of utilisation and exploitation of Copernicus D&I that generate impacts/benefits for end-users. The identification of impact drivers provides an understanding of how the specificities of each option affect and change stakeholder behaviour. To characterize the robustness of the different impact drivers, the following questions were asked:

- What are the Copernicus products/services available to address this impact driver/application?
- Who are the users of these products in the field of this application?
- Is there evidence of behavioural change among the users? Did the use of Copernicus data entails a change in habits, methods, compliance to legislation, etc.?
- What impacts are implied by the availability of Copernicus D&I brought by an option?

Such rational questioning enabled to refine and come up with a final list of in-scope Impact Drivers (See Road map of applications). For each impact driver in-scope, an Impact Pathway was developed. The purpose of the Impact Pathway is to understand how the use of Copernicus for certain applications affects society, the environment and/or the economy. Impact Pathway define the causal link between Copernicus outputs, the outcomes and the ultimate benefits resulting from the use of Copernicus in a defined field. Impact pathways support the development of the valuation methodology. They map out all the benefits stemmed from the different impact drivers and contribute to the development of an exhaustive list of benefits. This list is then refined by applying the filter of desirability, feasibility and materiality. In-scope benefits must be:

- an illustration of key Copernicus uses in line with the Union's political priorities (desirability);
- corroborated by sufficient data and analysis to be assessed (feasibility);
- significant in terms of valuation amount (order of magnitude, materiality);

After that filtering, the likely impacts were categorised into three groups: quantitatively assessable impacts (in monetary terms), qualitatively assessable impacts, and impacts to be considered out-of-scope. Decision was then made to focus only on quantitatively assessable benefits, plus some key qualitatively assessable benefits.

Finally, in-scope Impact Drivers and there derived benefits are classified according to the EARSC Taxonomy which is:

- Atmosphere and climate
- Land
- Built environment
- Marine and Ocean
- Disasters and geo-hazards
- Security

EARSC taxonomy is commonly accepted in the field of EO in Europe (EARSC, 2015; 2017). Using this taxonomy will facilitate comparability and consistency with all the work and studies carried out in the field of EO in Europe. The final list of impact drivers is presented in the next section.

- **Phase 3 – Forecast of how impacts are expected to evolve over time for each option.** During this phase, impacts related to each option were assessed with particular attention on how they affect end-users, with a dedicated focus on societal and environmental outcomes. Thanks to desk research and experts consultation, we have estimated the evolution of each impact over time, up to 2035.
- **Phase 4 – Quantification of impacts over time.** The analysis in this phase was relying on the assessment and monetisation of all the benefits enabled by Copernicus D&I for the baseline and evolution options. As explained in Phase 2, Impact Pathways supports the development of valuation

methodology. Several PwC valuation coefficient were used for the monetization of benefits, and aim to provide a monetary value to an environmental cost, relying on a dedicated methodology<sup>1</sup>.

Details on the methodology used to assess and monetise benefits are presented in the next section.

### 3.2 Roadmap of applications

A list of impact drivers has been developed to delineate the scope of the study. This roadmap of application has been reviewed and complemented with stakeholder consultations. The impact drivers are classified according to EARSC taxonomy.

The table below illustrates the roadmap of applications enabled by the availability of Copernicus D&I and that have been assessed.

Theme	Baseline : Impact drivers	Evolution options : Impact drivers
<b>Intermediate users</b>	EO Downstream Industry	
	EO Big Data Analytics	
<b>Atmosphere and Climate</b>	Air quality and pollution monitoring and forecasting	<b>Option 3A:</b> Anthropogenic CO2 emissions monitoring
	Solar energy monitoring and forecasting	
	Climate modelling	<b>Option 3B:</b> Arctic environment and snow evolution monitoring
	Additional impacts for atmosphere and climate change ( <i>qualitative impact</i> )	
<b>Land</b>	Crops monitoring – support to agriculture	<b>Option 3C &amp; 3D:</b> Enhanced Crops monitoring – support to agriculture
	Forestry management and protection	<b>Option 3D:</b> Enhanced Forestry management and protection
	Water resources management	<b>Option 3B:</b> Improved hydropower profitability <b>Option 3C:</b> Enhanced Water resources management
	Wetlands monitoring	<b>Option 3D:</b> Enhanced Wetlands monitoring
	CAP monitoring ( <i>qualitative impact</i> )	
	Ground elevation and ground motion monitoring	
	Support to land mapping and cadastral surveying ( <i>qualitative impact</i> )	
<b>Built Environment</b>	Urban area monitoring	<b>Option 3C:</b> Urban area monitoring (Heat Island)
	Offshore infrastructure management (offshore wind)	
	Oil and Gas infrastructure and exploration activities (onshore and offshore)	
	Mining and quarrying: minerals and raw materials extraction	<b>Option 3D:</b> Enhanced mining and quarrying: raw materials exploration and extraction
<b>Marine and Ocean</b>	Coastal monitoring	
	Marine resources management	
	Water quality monitoring	
	Ice monitoring to support navigation/ship routing in the Baltic region	
	Maritime navigation	
<b>Disasters and</b>	Fire detection and monitoring	<b>Option 3C:</b> Enhanced fire detection and monitoring

<sup>1</sup> For more details on the methodologies behind the valuation coefficients, please refer to: PwC, 2015, Valuing corporate environmental impacts, PwC Methodology document.

<b>Geo-Hazards</b>	Flood monitoring and forecasting	
	Pandemic monitoring ( <i>qualitative impact</i> )	<b>Option 3C:</b> Enhanced pandemic monitoring
<b>Security</b>	Control of illegal, unreported and unregulated fishing activities	<b>Option 4:</b> Enhanced control of IUU fishing activities in the EU
	Maritime safety – Search and Rescue	<b>Option 4:</b> Enhanced Maritime Safety - Search & Rescue
	Oil pollution monitoring	<b>Option 4:</b> Enhanced oil pollution monitoring
	Law enforcement and international crime	<b>Option 4:</b> Enhanced law enforcement and international crime
	EU border surveillance	<b>Option 4:</b> Enhanced EU borders surveillance
	Support to EU external actions ( <i>qualitative impact</i> )	

Table 2 - Roadmap of applications enabled by Copernicus D&I (Source: PwC analysis)

### 3.3 Challenges in assessing the benefits enabled by the Copernicus programme

Copernicus is creating new capabilities in Earth observation and monitoring which will be used by a wide range of intermediate and end users. It has the potential to create a range of entirely new service areas across multiple domains. Hence, applying an ex-ante impact assessment to Copernicus is challenging. In many domains, baseline is inexistent as there is no precedent for the service being performed. In other domains, even where data exists on the expected experience by end users, it may not be possible to predict and forecast the extent of the impact at EU or global level. These challenges create a number of issues when quantifying potential impacts:

1. The use/functionality of Copernicus capability by end users may not be clearly understood (by users themselves);
2. The appropriate baseline against which to assess benefits may be unclear;
3. Attribution of change to Copernicus is difficult to estimate;
4. Implementation measures led by Copernicus may require additional costs for governments or businesses. Such costs are not covered by this study.

Moreover it is important to note that each impact has required the development of a dedicated valuation model, which is specially designed for the contribution of Copernicus towards this particular application.

To respond to the different challenges detailed above, the team has proposed four main categories of mitigation measures as illustrated below.

Mitigation measures	
<b>Mitigation measure #1: methodologies used</b>	The main mitigation measure used by the team was to rely on standard and robust economic methodology that are accepted among economists. The approach used have been extensively used in many other sectors and many international institutions (i.e. World Bank, OECD, national governments), making the results comparable
<b>Mitigation measure #2: data sources used</b>	The team has used a wide range of secondary data sources, ranging from publicly available sources, commercial data or internal data repository, to be used as a proxy. On the top of secondary data, many primary data (through direct consultation with stakeholders) were collected, especially to understand the contribution of Copernicus D&I. It is worth noting that the team has also an extensive experience working with Copernicus D&I users



**Mitigation measure #3: scenario-based approach**

(intermediate and end-users).

By looking at a range of different scenario (pessimistic, average and optimistic), the team has leveraged the order of magnitude of impacts. The definition of these scenarios was based on the estimation of the contribution of Copernicus D&I that is in general assessed using range with low and high boundary (i.e. ranging between X and Y%). It is important to understand that other macro-economic factors may have impacted specific scenarios of some impact drivers (i.e. being able to reach Paris agreements targets).

**Mitigation measure #4: S-curve shaped user uptake**

User uptake (i.e. data dissemination, adoption rate) is always complex to assess and materialize. Given the similarities between adoption of new technologies and adoption of EO-based imagery, the decision was made to use an S-shaped approach to model user uptake and expected maturity of usage. Please refer to the report for more details.

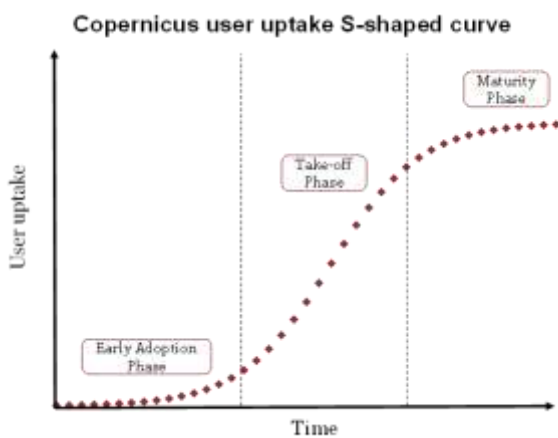
*Table 3 – Mitigation measures used to face assessment challenges*

# 4 Impact Assessment

## 4.1 Baseline assessment

The baseline option represents the scenario under which the Copernicus programme retains the same scope as it has currently. In this context, physical assets will need to be renewed to ensure continuity of data. It is the point of reference for the analysis of the different evolution options in the following section.

The user-uptake of the services offered by Copernicus has to be modelled in the baseline. Thanks to the Copernicus programme, the availability of new data and information which were previously not available for free, stimulates innovation and knowledge creation in the field of EO, GIS and EO Big Data. Innovation adoption or user uptake may be very different from one actor to another. Indeed, in some cases users rapidly adopt and integrate new services to support their activity, whereas other users require more time to absorb new technology and innovation products. This evolution can be modelled using the classic S-shaped curve<sup>2</sup>:



Such evolution follows 3 main phases in the Copernicus D&I user uptake:

- **Early adoption phase:** concerns very few individuals or companies that are innovators and have already strong knowledge about Earth observation, imagery and software (i.e. coders).

- **Take-off phase:** represents the vast majority of individuals and organisations trying to make use of Copernicus D&I. It relies on the knowledge stock already developed by early adopters

- **Maturity phase:** represents individuals and organisations more conservative or technology-averse.

<sup>2</sup> Adapted from Rogers, 2003; PwC analysis



## 4.1.1 Benefits for intermediate users

### 4.1.1.1.1 European EO downstream industry

The Copernicus programme was primarily designed to provide geospatial information in support of policy making. Such an open data programme in the field of geospatial information, providing free-of-use satellite-based imagery but also many sources of in-situ data, could have been seen as a threat for the private EO services industry. Nevertheless, the European downstream industry considers Copernicus D&I contribute to strengthen their competitive advantage by offering new business opportunities and raising awareness about the benefits derived from geospatial information both in Europe and outside. Additionally, acting as participants of the Copernicus programme and recipients of research and innovation funding (i.e. H2020), European intermediate users directly benefits from the Copernicus programme, stimulating their competitiveness on global markets. NSR (2016) estimations of European Compound Annual Growth Rate (CAGR) were used to project overall European intermediate users revenues over the period 2017 – 2025.

### 4.1.1.1.2 Contribution to Big Data in Europe

Big Data analytics based on satellite imagery is considered as a derivative of EO downstream information products' market<sup>3</sup> but they are not included in the previous section on European EO downstream industry revenues. This new market is enabled by the availability of very large sources of satellite-based imagery and in-situ data, available at no cost through open data programmes (i.e. Landsat and Copernicus) or at very low cost through large EO commercial constellations (i.e. Planet, Spire, etc.). Market of Big Data analytics based on satellite imagery relies on the processing, analysis and fusion of multiple images and other data sources in order to create intelligence not previously available; many of EO Big Data applications rely on statistics and econometric models linking information extracted from all the different datasets to create high value-added products. Even if the current market has not taken off in Europe yet, the Copernicus programme is expected to play a major role in stimulating this market over the next years, on account of the volume of data provided by Copernicus and the variety of data provided by Copernicus.

### 4.1.1.1.3 Summary of intermediate users benefits

<i>Copernicus EU benefits – EUR M</i>	<b>2017</b>	<b>2025</b>	<b>2035</b>	<b>Cumulative (2017 – 2035)</b>
<b>Low estimate</b>	119.2	396.7	657.6	7,637.2
<b>Medium estimate</b>	120.3	470.2	785.2	9,091.3
<b>High estimate</b>	121.2	543.8	912.8	10,545.3

*Table 4 - Copernicus total EU benefits for the three scenarios (EUR 2017, not discounted values) (Source: PwC analysis)*

## 4.1.2 Atmosphere & climate

### 4.1.2.1 Air quality and pollution monitoring and forecasting

Although air quality has improved significantly in Europe in past decades, air pollution concentrations remain high and a large proportion of Europe's population lives in areas with air pollution above EU limits<sup>4</sup>. Monitoring air quality is key to determine whether areas are meeting pollution targets and to assess the impact of air pollution policies. Satellite data on atmospheric composition has only recently been incorporated into air quality models, and is useful to monitor, assess and forecast air quality conditions by providing views of air pollution over large areas.

#### 4.1.2.1.1 Decreased exposure to air pollution as a result of air pollution alert services

The impacts from air quality and pollution warning systems, such as the application airTEXT, are valued by calculating the reduced exposure to air pollution in populations living in high pollution areas. CAMS regional air pollution forecast data is used as a key input in the models that provide the airTEXT warnings. Reduced exposure to air pollution as a result of this service leads to improved health, which is measured by the health valuations of asthma and chronic obstructive pulmonary disease (COPD) cases (it includes saved treatment costs and valuations of quality of life). The benefits enabled by Copernicus are calculated as follows:

<sup>3</sup> NSR, 2016. Satellite-Based Earth Observation (EO), 8th Edition. September, 2016.

<sup>4</sup> European Environmental Agency, 2017.

#### Decreased exposure to air pollution from air pollution alert services

##### Valuation approach



#### 4.1.2.1.2 Enabling policymakers to meet EU air pollution targets under the 2013 National Emission Ceilings Directive

Policy makers are provided with information to pre-emptively mitigate or reduce the impacts of severe air pollution episodes a few days in advance, rather than relying on real time observations. CAMS allows decision makers to select emission reduction strategies most adapted to each situation, enabling more effective public decision making on reducing air pollution. This can enable policies such as restricting traffic through cities, temporary speed reductions on motorways, changes in airplane schedules or compensating industrial energy users to reduce capacity during periods of high air pollution. Potential reductions in air pollution predominantly benefit health, but also agricultural productivity and visibility. The benefits enabled by Copernicus are calculated as follows:

#### Increased ability to meet EU air pollution targets

##### Valuation approach



#### 4.1.2.1.3 Summary of air quality and pollution monitoring and forecasting benefits

Copernicus EU benefits – EUR M	2017	2025	2035	Cumulative (2017 – 2035)
<b>Low estimate</b>	272.8	527.7	768.1	10,378.7
<b>Medium estimate</b>	409.1	791.5	1,143.8	15,559.7
<b>High estimate</b>	545.5	1,055.4	1,525.1	20,746.2

Table 5 - Copernicus total EU benefits for the three scenarios (EUR 2017, not discounted values) (Source: PwC analysis)

## 4.1.2.2 Solar energy monitoring and forecasting

With the recent NDC targets under the COP21 Paris Agreement as well as the revised European Renewable Energy Directive targeting a 27% share of renewables in the final energy consumption by 2030, renewable energy and, as part of it, solar energy has a significant role to play.

#### 4.1.2.2.1 Reduced costs of energy

Profitability of the solar energy market is going to increase in the next few years. There are several reasons for this: solar infrastructure prices are slowly decreasing<sup>5</sup>; European and often national directives push forward for a larger share of renewable energy in the energy mix, of which solar, along with wind, are crucial<sup>6</sup>; and environmental awareness of citizens has brought attention upon renewable energy sources as opposed to fossil fuel energy sources<sup>7</sup>. As such, Copernicus can play a part in the increase in profitability through its ability to help improve site selection and farm design. The benefits enabled by Copernicus are calculated as follows:

5 J. Doynne Farmer & François Lafond, 2016, “How predictable is technological progress?”, Research Policy, Issue 45, pp. 647-665

6 European Parliament website. (Online) Available at: [http://www.europarl.europa.eu/atyourservice/en/displayFtu.html?ftuId=FTU\\_5.7.4.html](http://www.europarl.europa.eu/atyourservice/en/displayFtu.html?ftuId=FTU_5.7.4.html) (Accessed: July 20th 2017)

7 Horizon 2020 programme, Intelligent Energy Europe. (Online) Available at: <https://ec.europa.eu/easme/en/intelligent-energy-europe> (Accessed: July 20th 2017)

*Reduced costs as a result of better infrastructure management leading to higher profitability thanks to the increase in solar energy on the market*

**Valuation approach**



#### 4.1.2.2.2 Reduced CO2 emissions

The role of satellite imagery and of Copernicus in enabling the reduction in CO2 emissions is directly linked to the benefit on the reduction of the cost of energy. As demand for electricity as a whole is inelastic, any increase in supply of solar energy displaces other (on average higher carbon) energy sources, leading to a reduction in CO2 emissions. Indeed, better site location and adapted farm design facilitate the increase in solar energy generation and CO2 emissions that would have come from other polluting energy sources are therefore avoided. As such, reduction of CO2 emissions is an indirect benefit of Copernicus. The benefits enabled by Copernicus are calculated as follows:

*Reduced CO2 emissions due to a decrease in reliance on fossil fuel energy sources*

**Valuation approach**



#### 4.1.2.2.3 Summary of solar monitoring and forecasting benefits

<i>Copernicus benefits – EUR M</i>	2017	2025	2035	Cumulative (2017 – 2035)
<b>Low estimate</b>	2.3	4.8	5.1	87.9
<b>Medium estimate</b>	3.5	6.8	7.2	125.7
<b>High estimate</b>	5.3	10	10.3	188.4

*Table 6 - Copernicus total EU benefits for the three scenarios (EUR 2017, not discounted values) (Source: PwC analysis)*

### 4.1.2.3 Climate modelling

The Copernicus Climate Change Service (C3S) provides comprehensive climate information, such as surface air temperature, sea-ice changes and other hydrological climate variables. C3S also conducts global and regional analysis which enables detailed information on climate change, particularly where direct observations are sparse. C3S products are used for modelling and projecting conditions in the European and global climate until the end of the century. The information of the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), to which C3S contributed, is made available for free which national and local decision makers as well as different sectors, such as water management, agriculture, energy and infrastructure, can use to support the European adaptation and mitigation response to climate change.

#### 4.1.2.3.1 Reduced economic loss from climate related extreme weather events

As a result of C3S climate modelling, greater accuracy in climate projections and forecasts is assumed, which policymakers can use to enhance climate change adaptation efforts. In particular, infrastructure can be located more effectively and efficiently in order to be resilient to future climate change. The benefits enabled by Copernicus are calculated as follows:

*Avoided economic losses from climate related extreme weather events*

**Valuation approach**



#### 4.1.2.3.2 Summary of climate modelling benefits

Copernicus EU benefits – EUR M	2017	2025	2035	Cumulative (2017 – 2035)
<b>Low estimate</b>	1.8	5.6	22.7	161.7
<b>Medium estimate</b>	2.2	6.7	27.2	194.0
<b>High estimate</b>	2.8	8.4	34.0	242.5

Table 7 - Copernicus total EU benefits for the three scenarios (EUR 2017, not discounted values) (Source: PwC analysis)

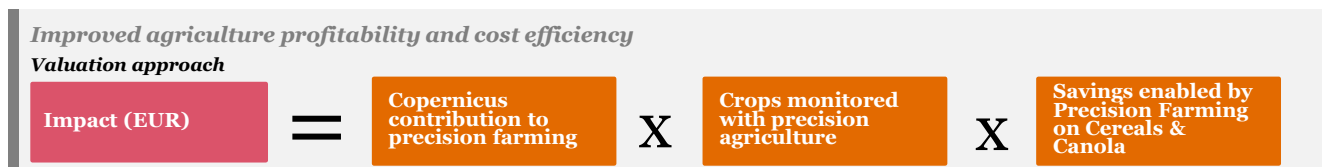
### 4.1.3 Land

#### 4.1.3.1 Crop monitoring – support to agriculture

The agriculture sector faces unprecedented challenges today. Farmers are confronted with a double issue: to keep producing to ensure food security whilst reducing their impact on the environment and the climate and protecting biodiversity. To do so, agriculture needs to increase its productivity by using new techniques like precision farming. In areas suffering from chronic food insecurity, detecting change in crop health in a timely manner is crucial to support early warning and strategic decisions to stave off hunger.

##### 4.1.3.1.1 Improved agriculture profitability and cost efficiency

Copernicus monitoring capacity can support the transition to a more productive and cost-effective agriculture model by enhancing adoption of precision farming techniques. Precision farming relies on the following principle: meeting the crop needs by providing the right inputs, at the right moment and in the right quantity. To do that, remote sensors are used to precisely measure crops biophysical variables (NDVI<sup>8</sup>, soil moisture, biomass...) inside a same field. Based on these accurate measures and on agronomist expertise, applications have been developed to supply intra-field level recommendation maps to farmers, in order to optimize input placement. Copernicus D&I are used to develop these recommendation maps (Geosys or Farmstar<sup>9</sup> for example). Varying the application of inputs and especially, of Nitrogen fertilizer, can reduce the costs, improve the nutritional quality of the crops, and maximize productivity. Hence the availability of Copernicus D&I in the field of agriculture, results in financial savings for farmers. The benefits enabled by Copernicus are calculated as follows:



##### 4.1.3.1.2 Reduce the negative impact on environment

As explained above, Copernicus services contribute to precision farming technologies and thus to the reduction of the use of Nitrogen fertilizer. There is a broad recognition that above-optimal applications of fertilizer nutrients lead to an enhanced risk of pollution. Fertilizers contain mainly Nitrogen (N) which is responsible for Nitrogen leaching, leading to underground water pollution, GHG emission (N<sub>2</sub>O) and air pollution (NO<sub>x</sub> and NH<sub>3</sub>). The benefits resulting from the reduction of Nitrogen surplus (crops can only absorb a certain dose of nutrient at certain time of their growth), are calculated as follows:



8 NDVI : Normalized Difference Vegetation Index

9 Airbus website. "Airbus boosts its capacity in the agricultural sector with European sentinel satellites"

#### 4.1.3.1.3 Improve food security

The main benefit of Copernicus related to food security is Early Warning for situation of crop stress or failure that can lead to humanitarian crisis (hunger). Satellite data provide information like soil moisture and rain fall estimation that support early forecasting of extreme weather events leading to harvest failure. The benefits of an early reaction has been evaluated and is clearly illustrated by crops insurance or climate risk insurance (Weather Index based). Indeed in, case of harvest failure payout are triggered more rapidly than emergency aid, preventing the crisis to evolve into a real famine. Small holders insurances can be a powerful tool against hunger<sup>10</sup> (G7 summit<sup>11</sup>) in vulnerable countries (climate risk). The model is based on this proxy:



#### 4.1.3.1.4 Summary of crop monitoring – support to agriculture benefits

Copernicus EU benefits – EUR M	2017	2025	2035	Cumulative (2017 – 2035)
<b>Low estimate</b>	98.2	757.3	1,479.6	15,462.2
<b>Medium estimate</b>	139.2	1,148.1	2,129.5	23,025.8
<b>High estimate</b>	186.8	1,564.3	2,930.0	31,711.1

Table 8 - Copernicus total EU benefits for the three scenarios (EUR 2017, not discounted values) (Source: PwC analysis)

### 4.1.3.2 Forestry Management and Protection

The challenges linked to forestry are not the same globally and at the European level. In Europe, forest is increasing slowly (slightly more than 1M ha every 5 years according to Eurostat<sup>12</sup>), but most of the forest's ecosystems are in a poor state and the legislation concerning sustainable forest management practices is flouted in too many cases. At global scale, the main issue is fighting deforestation to reduce carbon emissions resulting from forest destruction and degradation. This study focuses only on Europe. Access to a reliable monitoring tool like Copernicus, can lead to several benefits.

#### 4.1.3.2.1 Cost reduction in monitoring compliance to forest management best practices (for national forest agencies)

To implement better management practices and monitor the compliance of private forest owners to new directives, authorities can rely on EO data based tools and Copernicus is particularly relevant for this purpose. Indeed Copernicus data are free and provide equivalent spatial resolution and coverage as commercial images that National Forest agencies used to buy. The resulting financial benefits due to Copernicus, are calculated as follows (based on EARSC case study for Sweden<sup>13</sup>):



<sup>10</sup> WFP, (online) : <http://www.wfp.org/stories/weather-index-insurance-powerful-tool-against-hunger>

<sup>11</sup> G7, June 2015, InsuResilience initiative (online) : <http://www.mofa.go.jp/mofaj/files/000084023.pdf>

<sup>12</sup> [http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=for\\_area&lang=en](http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=for_area&lang=en) (Accessed: July 24th 2017)

<sup>13</sup> EARSC case study on Copernicus Economic Value: Forest Management in Sweden, January 2016

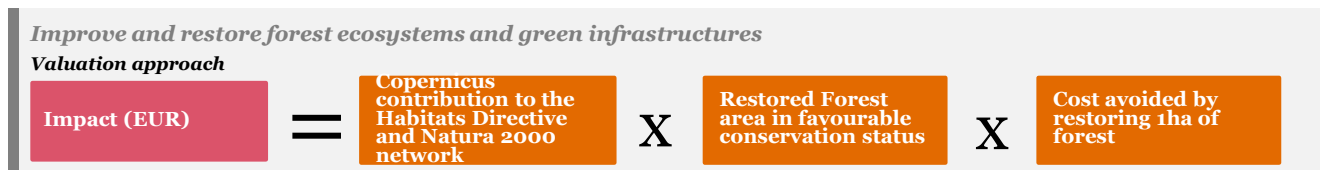
#### 4.1.3.2.2 Improved yields in forest industry thanks to sustainable management (increasing volume and quality of timber on the long term)

In Europe (legislation is similar among the different Member States), when a forest owner wishes to fell an area of forest (clear cut), he is obliged to notify national authorities. Afterwards, the owner has to replant the trees, and to do a first “pre-commercial thinning” within 10 years. Thanks to free Copernicus data, Forest Agencies can develop accurate “clear-cut” maps and spot non-compliant areas. Knowing that they are carefully watched, private forest owners start to change their behaviour by adopting more sustainable management practices which leads to improve yields and increased long term benefits for the forest industry. Hence Copernicus induced benefit are calculated as follows:



#### 4.1.3.2.3 Improve and preserve forest ecosystems and green infrastructures

In 1992, in response to the alarming status of biodiversity in Europe, EU governments unanimously adopted the Habitats Directive and its main component: the Natura 2000 network. The Directive requires that MS submit a report on biodiversity conservation status in their zone, every 6 years. Copernicus products are clearly relevant to assess ecosystems conservation status, to monitor Natura 2000 network, and so, to improve forest ecosystems through the Habitat Directive implementation. The environmental benefit enabled by Copernicus is calculated as follows<sup>14</sup>:



#### 4.1.3.2.4 Summary of forestry management and protection benefits

<i>Copernicus benefits – EUR M</i>	2017	2025	2035	Cumulative (2017 – 2035)
<b>Low estimate</b>	16.6	215.1	489.9	4,628.6
<b>Medium estimate</b>	30.3	393.4	927.0	8,603.5
<b>High estimate</b>	44.1	571.7	1,364.1	12,578.3

*Table 9 - Copernicus total EU benefits for the three scenarios (EUR 2017, not discounted values) (Source: PwC analysis)*

### 4.1.3.3 Water resources management

Water is a limited resource that needs to be preserved. The number of areas affected by drought has increased by 20% in the past 30 years<sup>15</sup>. Water scarcity in certain regions leads to an increasing competition between farmers, industry sector (e.g. hydropower, transport) and citizens for access to water. Thanks to satellite imagery, decision makers (public authorities, farmers, dam managers...) can better assess the level of supply and demand for water in order to ensure a sustainable, optimized and equitable management of this vital resource.

#### 4.1.3.3.1 Improve profitability in the hydropower sector

Copernicus data support hydroelectric plant management, by providing information on water catchment properties, precipitation and the amount of snow stored during winter. These are extremely useful to energy providers for optimizing hydroelectric power production, regulating dam levels and setting electricity prices.

<sup>14</sup> Valuation coefficient use: corresponds to the economic value of lost ecosystem services associated with the conversion and/or degradation of forest areas.

<sup>15</sup> ESA Portal (Online) : [http://www.esa.int/Our\\_Activities/Observing\\_the\\_Earth/Copernicus/Land](http://www.esa.int/Our_Activities/Observing_the_Earth/Copernicus/Land)



Benefits are even higher when rivers are not equipped with in-situ stations (in developing countries) or cross a boarder. Copernicus products can add quality and reduce uncertainty in the Hydrological models used by hydropower plants, resulting in increased benefits:



#### 4.1.3.3.2 Improve Agriculture productivity (irrigation management)

The largest use of freshwater resources is for agriculture irrigation. Sentinel-1 provides the Soil Water Index which, combined with other Copernicus D&I, provides very important inputs to assess the water requirement of crops and to forecast water stress situation. Optimized water inputs can be deducted from Copernicus data and so farmers can reduce their overall level of irrigation. Benefit calculations are as follows:



#### 4.1.3.3.3 Save environmental resources (ground water)

Copernicus enables water savings through better irrigation management. Using less water for irrigation reduces the need for pumping underground water. Hence underground water depletion is diminished and environmental resources are saved for other services (industry, citizen health...). The benefits enabled by Copernicus are calculated as follows:



#### 4.1.3.3.4 Summary of water resources management benefits

Copernicus EU benefits – EUR M	2017	2025	2035	Cumulative (2017 – 2035)
<b>Low estimate</b>	19.6	121.0	238.8	2,586.5
<b>Medium estimate</b>	24.0	158.4	323.9	3,447.7
<b>High estimate</b>	33.0	234.4	485.7	5,103.3

Table 10 - Copernicus total EU benefits for the three scenarios (EUR 2017, not discounted values) (Source: PwC analysis)

### 4.1.3.4 Wetlands monitoring

Wetlands are among the most threatened ecosystems in Europe, having been subject to major losses in recent decades. However, wetlands are some of the planet’s most productive ecosystems hosting very rich biodiversity and are very efficient for carbon sequestration. In Europe, most of the wetlands are protected by the EU Directive Habitat and the Natura 2000 network. Similar as for the section on Forest Management, Copernicus products’ portfolio are relevant for the monitoring of Natura 2000 network to meet the requirements of the Habitats Directive in terms of status assessment.

#### 4.1.3.4.1 Improve restoration of wetlands ecosystems’ services

By providing a powerful reporting tool to environmental authorities, Copernicus contribute to the restoration of Wetlands in Europe. Details of the model developed are presented below:



**Improve restoration of wetlands ecosystems**  
**Valuation approach**



**4.1.3.4.2 Summary of wetlands monitoring benefits**

Copernicus EU benefits – EUR M	2017	2025	2035	Cumulative (2017 – 2035)
<b>Low estimate</b>	7.4	222.1	434.5	4,594.8
<b>Medium estimate</b>	12.4	370.1	724.2	7,658.2
<b>High estimate</b>	17.4	518.2	1,013.9	10,721.4

Table 11 - Copernicus total EU benefits for the three scenarios (EUR 2017, not discounted values) (Source: PwC analysis)

**4.1.3.5 CAP monitoring**

This section has been assessed qualitatively considering the lack of information on enabled savings for authorities and on the Copernicus contribution to the CAP (Common Agricultural Policy). CAP monitoring controls rely on a complex framework named IACS (Integrated Agricultural Control System). It is the most important system for the management and control of payments to farmers made by the Member States in application of the CAP. The IACS relies partly on Control with Remote Sensing (CwRS). CwRS includes On-The-Spot-Checks (OTSC), which can be also done with on field visits. OTSC are currently conducted on a sample of parcels (5% of the farms) and they require VHR and HR (10-20 m) images. Copernicus images could play an important role in the IACS framework.

**4.1.3.5.1 Cost reduction in the monitoring of the CAP**

By replacing commercial HR images bought by the JRC for the CwRS and especially for OTSC, Copernicus can lead to cost reduction for MS Paying Agencies. A use case is presented below:

**Use Case: Sentinel’s images for CwRS<sup>16</sup>**

For each campaign, MS Paying Agencies submit their images request (HR, VHR, area of interest, temporal window...) on the G4CAP portal, which is managed by the JRC. For the 2017 campaign the total area to be acquired is 453,624 km<sup>2</sup> in VHR and 603,197 km<sup>2</sup> in HR (vs 862,923 km<sup>2</sup> in 2016). Among the HR images, 30% could be replaced by Sentinel 2 data since the JRC has certified that the CAP CwRS technical requirements were met<sup>17</sup>. Replacing all the HR images by Sentinel data would save around EUR 400 K, which seems small but the real savings would come from the more efficient management of the IACS and especially for OTSC. For the 2017 campaign 16 out of 32 MS Regions were using Sentinel data for their controls (S2 alerts). They were 11 out of 32 in 2016.

**4.1.3.5.2 More efficient, effective and traceable monitoring system for the CAP**

Sentinels’ capabilities, plus the “free and open” access to data, will lead to a more frequent and more efficient availability of high-resolution imagery for CAP management. The wide coverage and frequent data capture of Sentinel-1 and 2, allow the development of times series which lead to a shift from sample checks at a certain date, to ongoing monitoring at national scale. This change corresponds better to agricultural activities, heterogeneity of land characteristics and soil parameters. Several Member States Paying Agencies have already launched initiatives to use Copernicus for CAP monitoring.

**Use Case: CZECH AGRICULTURE PROJECT<sup>18</sup>**

The SZIF (The Czech paying agency) has set up a proof concept to demonstrate capability of the Copernicus Sentinels for CAP monitoring. Based on Sentinel-1 and 2 plus in-situ inputs, they have developed crop type maps (classification), where crops data are integrated and aggregated into LPIS parcels. It enables results like: more regular LPIS update, better risk analysis for a more effective OTSC sample selection, support to decision on recovery for undue payment thanks Copernicus time series (traceability).

<sup>16</sup> “Closing Campaign 2016, status Image provision 2017, and preparing for 2018”, Johan Astrand (JRC), May 2017

<sup>17</sup> “New sensors benchmark report on Sentinel-2A”, JRC, 2015

<sup>18</sup> “Potential Use of Sentinels for the IACS purposes (Czech Agri Project)”, SZIF, 2016

Besides, the regulation concerning the use of new technologies for CAP monitoring is evolving quickly towards a new “full monitoring” approach to simplify the CAP controls.

#### **Use Case: Full monitoring approach (2018)**<sup>19</sup>

*In May 2017, the European Commissioner for Agriculture, Phil Hogan, claimed for an increasing use of Space Technology to simplify the CAP<sup>20</sup>. As from 2018, MS may opt for full monitoring approach (amendment of the Regulation EU 809/2014). “Monitoring” means a continuously tracking and tracing of land activities, based on AT LEAST Sentinel data. It should cover 100% of the area, and be automated as much as possible (automated classification of the activities, type of crops...). The current OTSC should be substituted by continuous images (no more samplings, no multiple visits). Administrative costs will be reduced and compliance and performance should be improved. Copernicus’ benefit will be very significant within this approach, as Sentinel will be the prime source of data (still complemented with VHR).*

#### **4.1.3.5.3 Better implementation of the Greening Measures**

By being able to detect activities on ground on a continuous time basis, Sentinel data are particularly relevant for the controls relative to “greening measures”, especially for the following examples: check on permanent Grassland (thanks to Copernicus High Resolution Layer), detection of change in declared fallow land, check on the type of crops declared (diversification), etc.

### **4.1.3.6 Support to land mapping and cadastral surveying**

Given the scarcity of quantitative data and the multiple resulting impacts (diluted into other applications) of this impact driver, it was not possible to monetise this application. However it is important to analyse it at least qualitatively as mapping of Land use/Land cover is one of the primary goals of Copernicus Land Services. National Mapping Agencies, Cadastral and Land registration authorities can be users of Copernicus products, as well as providers of data (e.g. EuroGeographics) to enhance Copernicus Services (for the Mapping emergency service for example). Mapping Agencies can exploit the different Sentinel datasets and Copernicus Services to create their own individual land monitoring products. Sentinel 1 is particularly interesting, to develop a Digital Land Cover Model as it provides information on soil moisture, soil surface roughness and vegetation structure. Concerning Cadastral update and upkeep, Cadastral agencies are using VHR ortho-imagery for their survey. But Copernicus can be a complementary source of data for them. Especially when it comes to change detection: new building, increase in agriculture parcel, etc. Copernicus Land Services can support the transition to a more “dynamic” cadastral system (updated in “real” time), and to the digitalization of Land registration systems.

Above all, Copernicus could be the first access point of harmonised, pan-European, authoritative geospatial information and services, enabling cost reduction and efficiency gain.

### **4.1.3.7 Ground elevation and ground motion monitoring**

The monitoring of surface deformation is an important stake as current infrastructure may not be ready to face its consequences (e.g. gas pipelines damaged by ground subsidence could lead to gas explosion). The use of Synthetic Aperture Radar (SAR) and Optical (multispectral) imagery is therefore key for ground observation and mapping. Copernicus can in particular be useful to support infrastructure management, facilities construction or tunnelling<sup>21</sup> thanks to its ability to track subsidence.

#### **4.1.3.7.1 Reduced maintenance costs and improved safety thanks to efficient monitoring of subsidence (pipeline management support)**

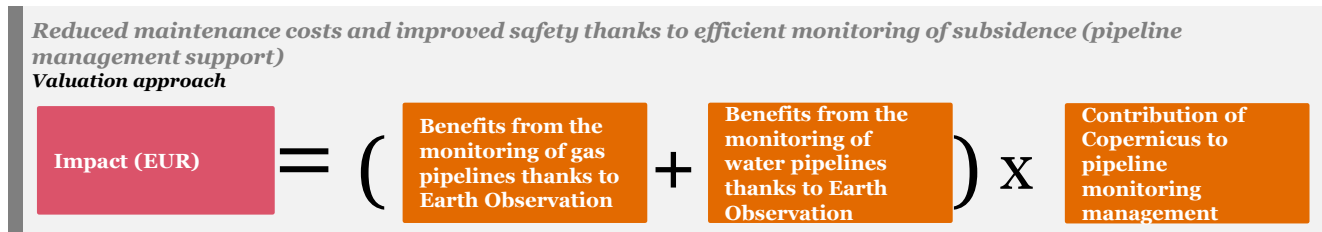
Avoiding pipeline incidents due to ground subsidence is a major stake considering the damages that could be caused by a gas pipeline break for instance. To help support pipeline management, the use of InSAR (Interferometric SAR) maps can be very useful. These maps are based on SAR (Synthetic Aperture Radar)

<sup>19</sup> “Introduction of monitoring & investing in the future”, Arie Van der Gref, 2017 IACS Workshop, May 2017

<sup>20</sup> Farmers Journal (Online) : “Space technology to simplify the CAP”, Phil Hogan, 2017

<sup>21</sup> Copernicus newsletter. (Online) Available at: <http://newsletter.copernicus.eu/article/successful-launch-sentinel-1-marks-beginning-new-era-copernicus-programme> (Accessed: July 26th 2017)

images, such as images provided by Sentinel-1, which enable to detect the changes in height of the surface of the Earth and thus of ground movement. However, Sentinel-1 data cannot be used alone to build such maps. Considering its resolution, it only enables to detect areas considered at risk and then Very High Resolution (VHR) data are used to get more details on hot spots. The two are fully complementary: Sentinel-1 gives information at the scale of a street, and VHR data at the scale of a building. The benefits enabled by Copernicus are calculated as follows:



#### 4.1.3.7.2 Summary of ground elevation and ground motion monitoring benefits

<i>Copernicus EU benefits – EUR M</i>	2017	2025	2035	Cumulative (2017 – 2035)
<b>Low estimate</b>	28.9	40.8	50.2	789
<b>Medium estimate</b>	33.6	44.9	55.2	867
<b>High estimate</b>	36.6	49.0	60.3	947

*Table 12 - Copernicus total EU benefits for the three scenarios (EUR 2017, not discounted values) (Source: PwC analysis)*

## 4.1.4 Built environment

### 4.1.4.1 Urban Area Monitoring

The growth and densification of urban areas pose social, economic and environmental challenges as the health, comfort and consumption needs of city dwellers must be addressed while environmental damages caused by human activities and excessive resource consumption must be avoided. Copernicus can be used as a key asset to collect and facilitate the access of necessary data enabling the analysis of urban drivers and the monitoring of urban environment.

#### 4.1.4.1.1 Reduced road traffic accidents:

Satellite imagery can support traffic management systems in increasing the level of road safety in urban areas by providing additional data on areas and road segments which are at risk for both road users and pedestrians. Copernicus data providing information on land cover, atmosphere and climate, combined with traffic, road and transport data represent an efficient tool for both road administrations in charge of guaranteeing the monitoring and maintenance of road and transport infrastructures, and policy makers in establishing sanctions preventing abusive and irresponsible road behaviour. The benefits enabled by Copernicus are calculated as follows:



#### 4.1.4.1.2 Reduced mortality rate caused by the effects of Urban Heat Islands:

Remote sensing thermal infrared data can be utilised to measure Land Surface Temperature (LST) in a much faster, simpler and more efficient way than non-space borne data collected by in-situ temperature sensors placed on tall towers, tethered balloons, aircraft sensors, etc., as a global view of concerned cities is allowed and

leads to a faster mapping of urban hot spots. The Sea and Land Surface Temperature Radiometer (SLSTR) mounted on Sentinel-3 satellites provides a range of thermal measurements products enabling the detection and mapping of Urban Heat Islands. The benefits enabled by Copernicus are calculated as follows:

*Reduced Fatalities caused by Urban Heat Islands*

*Valuation approach*

$$\text{Impact (EUR)} = \text{Contribution of Copernicus to the reduction of fatalities caused by UHI} \times (\text{Number of fatalities in baseline scenario} - \text{Number of fatalities in mitigation scenario}) \times \text{Statistical value of life}$$

4.1.4.1.3 Summary of urban area monitoring benefits

<i>Copernicus EU benefits – EUR M</i>	2017	2025	2035	Cumulative (2017 – 2035)
<b>Low estimate</b>	3.6	16.7	68.7	486.9
<b>Medium estimate</b>	7.3	38.2	168.9	1,156.6
<b>High estimate</b>	11.3	64.8	305.2	2,026.8

Table 13 - Copernicus total EU benefits for the three scenarios (EUR 2017, not discounted values) (Source: PwC analysis)

### 4.1.4.2 Offshore Wind Renewable Energy infrastructure management

According to OECD’s Ocean Economy Report<sup>22</sup>, the offshore wind energy market holds high prospects for long-term growth. Copernicus can give an informed optimized location for potential wind energy farm sites taking into account the amount of wind available, wave height, wind speed, weather conditions in the area of interest and whether they pose a risk on the infrastructure. This information can also be used to refine the design of offshore platforms so that they withstand weather conditions of the desired location, and to monitor and assess the Operations and Maintenance (O&M) costs of the wind farm<sup>23</sup>.

4.1.4.2.1 Reduced costs and increased productivity in wind energy

Thanks to the optimized locations of wind farm sites and the assessments provided by Copernicus, higher production rates from farms can be expected, leading to the required productivity of wind energy being achieved at smaller costs. Thus, the revenues of offshore wind renewable energy increase. The benefits enabled by Copernicus are calculated as follows:

*Increased revenues due improved offshore wind energy production*

*Valuation approach*

$$\text{Impact (EUR)} = \text{Installations of offshore wind energy capacity} \times \text{Attribution of part of this increased generation to Copernicus} \times \text{Reduced toxic emissions and saved water per KWh of wind energy} \times \text{Valuation coefficients of toxic emissions and wasted water}$$

4.1.4.2.2 Social and Environmental benefits: Reduced toxic emissions of CO<sub>2</sub>, SO<sub>2</sub>, and NO<sub>x</sub>

If more of Europe’s need for generated power is satisfied by renewable energy sources, less generation from fossil fuels will be required. Therefore, to look at the environmental benefits of offshore wind energy, the displaced toxic emissions of a KWh thanks to clean energy generated compared to fossil fuel energy emissions can be calculated. Similarly, the required cooling water for fossil fuel combustion that is saved can be determined. The benefits enabled by Copernicus are calculated as follows:

22 OECD, 2016, The Ocean Economy in 2030 (Online). Available at: <http://www.oecd.org/sti/futures/the-ocean-economy-in-2030-9789264251724-en.htm>

23 EC, ‘Environmental Monitoring of Marine Renewable Energy Farms’. Copernicus User Uptake Information Sessions, Renewable Energies/Marine

Reduced toxic emissions and avoided waste of water

Valuation approach



4.1.4.2.3 Summary of offshore wind renewable energy infrastructure management benefits

Copernicus EU benefits – EUR M	2017	2025	2035	Cumulative (2017 – 2035)
<b>Low estimate</b>	15.7	150.3	433.8	3,551.1
<b>Medium estimate</b>	40.4	286.2	839.8	6,923.4
<b>High estimate</b>	98.8	715.6	1,959.5	16,605.2

Table 14 - Copernicus total EU benefits for the three scenarios (EUR 2017, not discounted values) (Source: PwC analysis)

### 4.1.4.3 Oil and Gas infrastructure management/development and exploration activities

The Oil & Gas industry has been using satellite-based imagery for more than a decade and recent initiatives, such as the Earth Observation for Oil & Gas (EO4OG), have stimulated dissemination of EO data and products in daily activities of O&G companies. The importance of geospatial data and information in O&G activities varies extensively from one company to another. O&G companies usually have strong in-house capabilities related to imagery processing and analysis to support exploration and exploitation, stimulating their interest for Copernicus data (i.e. Sentinel-2 data to support road and pipeline routing) and information (i.e. wind and waves forecasts for off-shore infrastructure planning).

4.1.4.3.1 Reduced costs and increased revenues for the European O&G industry

Copernicus D&I enable the O&G industry to save costs for the O&G sector, which makes it cheaper to supply O&G. The use of O&G has a negative impact on the environment so cheaper supply of O&G should also have negative impact on the environment. Nevertheless, the O&G demand is completely inelastic, meaning that a lower or higher price of oil does not impact its level of consumption. In this context, having a cheaper supply of O&G thanks to Copernicus will not lead to additional negative externalities for the environment.

Reduced cost and increased revenues for the European Oil & Gas industry

Valuation approach



4.1.4.3.2 Summary of oil & gas infrastructure management/development benefits

Copernicus EU benefits – EUR M	2017	2025	2035	Cumulative (2017 – 2035)
<b>Low estimate</b>	131.7	429.0	429.0	6,971.0
<b>Medium estimate</b>	242.5	583.9	583.9	9,771.4
<b>High estimate</b>	360.0	762.6	762.6	13,006.8

Table 15 - Copernicus total EU benefits for the three scenarios (EUR 2017, not discounted values) (Source: PwC analysis)

## 4.1.4.4 Mining and quarrying: minerals and raw materials extraction

The mining and quarrying sector is considered one of the major sectors by the European Union, as emphasized by the EUR 600 M invested in the frame of Horizon 2020 for the period 2014-2020<sup>24</sup>. Indeed, in 2008, the European Commission launched the Raw Material Initiative (RMI) aimed at developing a European strategy as to the access and use of non-energy raw materials. Considering the importance of the raw materials sector, Earth Observation and in particular Copernicus, has a strong role to play and can be useful during all phases of mining activities<sup>25</sup>. More precisely, in the mapping phase, Copernicus data can support mineral exploration through the modelling of the mineral composition of potential mining areas. In the operation phase, Sentinel-1 can be useful in particular to prevent mining subsidence<sup>26</sup>. However, currently, the potential of Earth Observation in the mining sector is considered under-exploited and Copernicus uptake is of reduced maturity<sup>27</sup>.

### 4.1.4.4.1 Improved mine site surveying, resource reserves exploration and drilling and blasting leading to an increased output

In the past years, there have been few new mining projects in Europe. This means that European projects are either in the operation phase or in the closure phase<sup>28</sup>, which implies that Earth Observation-based applications useful for the mining sector in Europe mostly concern on-site activities and post-closure management. Moreover, if, in the field of mining and quarrying applications, satellite data can prove really useful, it is mostly navigation data that are essential. Earth observation imagery is often only complementary to navigation data and is thus used in a limited number of applications<sup>29</sup>. The benefits enabled by Copernicus are calculated as follows:



### 4.1.4.4.2 Summary of mining and quarrying: minerals and raw materials exploration and extraction benefits

Copernicus EU benefits – EUR M	2017	2025	2035	Cumulative (2017 – 2035)
<b>Low estimate</b>	0.49	2.78	4.45	54.9
<b>Medium estimate</b>	0.73	4.17	6.67	82.3
<b>High estimate</b>	0.98	5.56	8.89	109.8

Table 16 - Copernicus total EU benefits for the three scenarios (EUR 2017, not discounted values) (Source: PwC analysis)

## 4.1.5 Marine & ocean

### 4.1.5.1 Coastal Area Monitoring

Natural marine and environmental factors such as waves, winds, tides, storms and currents as well as human factors such as coastal urbanisation and economic activities have an impact on coastal land areas and are

<sup>24</sup> European Commission, 2016, Report : Copernicus for Raw Materials workshop (Online). Available at: [http://workshop.copernicus.eu/sites/default/files/content/attachments/ajax/raw\\_materials\\_ws\\_report.pdf](http://workshop.copernicus.eu/sites/default/files/content/attachments/ajax/raw_materials_ws_report.pdf)

<sup>25</sup> European Commission, 2016, Report : Copernicus for Raw Materials workshop (Online). Available at: [http://workshop.copernicus.eu/sites/default/files/content/attachments/ajax/raw\\_materials\\_ws\\_report.pdf](http://workshop.copernicus.eu/sites/default/files/content/attachments/ajax/raw_materials_ws_report.pdf)

<sup>26</sup> Copernicus newsletter. (Online) Available at: <http://newsletter.copernicus.eu/article/successful-launch-sentinel-1-marks-beginning-new-era-copernicus-programme> (Accessed: July 26th 2017)

<sup>27</sup> European Commission, 2016, Report : Copernicus for Raw Materials workshop (Online). Available at: [http://workshop.copernicus.eu/sites/default/files/content/attachments/ajax/raw\\_materials\\_ws\\_report.pdf](http://workshop.copernicus.eu/sites/default/files/content/attachments/ajax/raw_materials_ws_report.pdf)

<sup>28</sup> Benecke N. et al., 2012, GMES4Mining - Innovative Geoservices for Exploration and Monitoring of Mining Areas (Online); Available at: [http://www.gmes4mining.info/public/AIMS2012\\_GMES4Mining\\_Benecke\\_et\\_al.pdf](http://www.gmes4mining.info/public/AIMS2012_GMES4Mining_Benecke_et_al.pdf)

<sup>29</sup> PwC, 2017, Dependence of the European Economy on Space Infrastructures: Potential Impacts of Space Assets Loss



drivers leading to coastal degradation. Copernicus provides data supporting shoreline monitoring and coastal management activities.

#### 4.1.5.1.1 Reduce costs of land planning

The information provided by Copernicus data on coastal areas enable a fast analysis of areas concerned by coastal erosion and therefore represent a valuable input to better decision making when planning coastal protection actions. Compared to non-space borne data, Earth Observation and Copernicus data are much timely to collect and analyse when examining a wide area. The benefits enabled by Copernicus are calculated as follows:



#### 4.1.5.1.2 Prevent loss of land

Information provided by Copernicus data on coastal areas allow quicker and enhanced analysis of areas concerned by coastal erosion. Therefore, faster and better decision making is done when planning the construction of coastal infrastructures. Copernicus allows the reduction or at least the containment of coastal loss. The benefits enabled by Copernicus are calculated as follows:



#### 4.1.5.1.3 Protected coastal population against natural disasters

Copernicus data can contribute to the protection of coastal population against natural disasters by providing models on marine mechanisms such as sea level, wave intensity, drifts, and winds that lead to a better identification of specific areas exposed to floods and severe storms' direct effects and aftereffects. The benefits enabled by Copernicus are calculated as follows:



#### 4.1.5.1.4 Protection of agriculture

Copernicus data supports the detection of saltwater intrusion into groundwater sources and helps researchers in understanding the occurrence of the phenomenon and therefore its containment and the reduction of its effects. The benefits enabled by Copernicus are calculated as follows:



#### 4.1.5.1.5 Summary of coastal area monitoring benefits

<i>Copernicus benefits – EUR M</i>	2017	2025	2035	Cumulative (2017 – 2035)
<b>Low estimate</b>	37.2	52.8	66.6	1,014.1
<b>Medium estimate</b>	79.6	113.8	143.3	2,182.6
<b>High estimate</b>	154.1	219.4	276.7	4,211.8

Table 17 - Copernicus total EU benefits for the three scenarios (EUR 2017, not discounted values) (Source: PwC analysis)



## 4.1.5.2 Marine resources management

Sustainable fishing is a key consideration for food security, as seafood plays a significant role in the human diet, both in Europe and worldwide<sup>30</sup>. As the population increases, pressure on aquaculture production will only grow. As the wild catch of many species at sea have already exceeded sustainable levels, this need can only be met by expanding aquaculture. Therefore, the use of satellite imagery and modelled products and services are key to monitor conditions, support site optimisation and quotas, and improve practices for the protection of protected species.

### 4.1.5.2.1 Increased productivity in the fishing industry – wild fishing

Empirical evidence has shown that satellite derived ocean colour (chlorophyll-a) and sea surface temperature data can be used for prediction of Potential Fishing Zones (PFZ). The benefits of satellite derived PFZ advisories were that search time to locate fish schools and associated mean catch per unit effort (CPUE) in PFZ areas was almost twofold in comparison to the CPUE of non-PFZ areas<sup>31</sup>. The benefits enabled by Copernicus are calculated as follows:



### 4.1.5.2.2 Summary of water resources management benefits

<i>Copernicus EU benefits – EUR M</i>	2017	2025	2035	Cumulative (2017 – 2035)
<b>Low estimate</b>	6.3	17.9	37.0	386.2
<b>Medium estimate</b>	9.4	26.9	55.5	579.2
<b>High estimate</b>	12.6	35.8	74.0	772.3

*Table 18 - Table 19 - Copernicus total EU benefits for the three scenarios (EUR 2017, not discounted values) (Source: PwC analysis)*

## 4.1.5.3 Water quality monitoring

Water quality monitoring provides information to support public policy and regulatory decisions on health and environmental issues, which can assess and prevent damages to ecosystems and coastal communities and economies. Data and products are provided by Copernicus on ocean temperature, currents, and the chlorophyll content of the ocean's surface levels alongside other biogeochemistry factors associated with ocean colour, that enable the analysis of algal and jellyfish blooms. Furthermore, ocean current models enable the search areas of plastic pollution to be optimised, a subject which is receiving increasing attention.

### 4.1.5.3.1 Reduce plastic pollution in the oceans (economic impact)

As a result of ocean currents, plastic pollution often converges in accumulation zones known as gyres. Major marine plastic pollution removal organisations expect that due to the available technologies, including ocean current models, schemes involving plastic pollution collection barriers can remove plastics at an effectiveness of 4.2% annually. Current models assume a clean-up start date of 2018, with full implementation in 2020. The benefits enabled by Copernicus are calculated as follows:

<sup>30</sup>Copernicus Brief. (Online) Available at:

[http://www.copernicus.eu/sites/default/files/documents/Copernicus\\_Briefs/Copernicus\\_Brief\\_Issue24\\_Aquaculture\\_Sep2013.pdf](http://www.copernicus.eu/sites/default/files/documents/Copernicus_Briefs/Copernicus_Brief_Issue24_Aquaculture_Sep2013.pdf) (Accessed: July 20th 2017)

<sup>31</sup> Based on the "Satellite based integrated potential fishing zone advisories: a feasibility analysis in the coastal water of West Bengal" study (online). Available at :

<https://link.springer.com/article/10.1007/s12595-013-0088-x> (Access: July 21th 2017)

### Reduced plastics in the oceans

#### Valuation approach

$$\text{Impact (EUR)} = \text{Tonnes of plastic able to be removed from oceans} \times \text{Natural capital cost per tonne of plastic pollution} \times \text{Annual roll out percentage}$$

#### 4.1.5.3.2 Increased productivity in the fishing industry associated with harmful algal bloom forecasts

The analysis is made on Portugal, France, Spain, Ireland and Scotland which account for 25% of the EU's aquaculture production<sup>32</sup>. For these five countries, a study was conducted showing that access to the harmful algal bloom forecasts gave a direct benefit of productivity increase in the affected farms, with the aim of an even bigger productivity increase should the necessary technologies be implemented across the farms (e.g. oxygenation systems<sup>33</sup>). The benefits enabled by Copernicus are calculated as follows:

### Increased productivity associated with harmful algal blooms

#### Valuation approach

$$\text{Impact (EUR)} = \text{Value of production in aquaculture} \times \text{Percentage increase in productivity} \times \text{Annual roll out percentage}$$

#### 4.1.5.3.3 Economic impact of reduced harmful algal bloom related illnesses

It has been estimated that the annual economic impact of harmful algal blooms on public health is approximately USD 20 million<sup>34</sup>. The studies calculate the economic impact of harmful algal bloom illnesses using both the treatment costs and productivity decrease due to toxic finfish and shellfish consumption. Harmful algal bloom related illnesses are transmitted by consumption of seafood. It is expected that upon receiving algal bloom forecasts showing imminent contamination, testing would occur daily rather than weekly<sup>35</sup>, and so additional toxic finfish and shellfish would be diverted from being sold for consumption. The benefits enabled by Copernicus are calculated as follows:

### Reduced illnesses associated with harmful algal blooms

#### Valuation approach

$$\text{Impact (EUR)} = \text{Percentage reduction in illnesses associated with increased testing} \times \text{Total economic impact of harmful algal blooms} \times \text{Annual roll out percentage}$$

#### 4.1.5.3.4 Economic impact of reduced jellyfish stings

Using Copernicus data, the Med-JellyRisk project, a project assessing the socio-economic impacts of jellyfish blooms and the implementation of mitigation countermeasures, monitors jellyfish risk at beaches, and communicates this to beach users through its mobile application. The benefits enabled by Copernicus are calculated as follows:

### Reduced treatment costs associated with jellyfish sting

#### Valuation approach

$$\text{Impact (EUR)} = \text{Percentage reduction in stings associated with increased awareness} \times \text{Total economic impact of jellyfish stings} \times \text{Annual roll out percentage}$$

#### 4.1.5.3.5 Summary of water quality monitoring benefits

Copernicus Global benefits – EUR M	2017	2025	2035	Cumulative (2017 – 2035)
<b>Low estimate</b>	0.8	2.5	5.1	50.1

<sup>32</sup> PwC analysis.

<sup>33</sup> Study conducted using Copernicus data (Online). Available at: [http://cordis.europa.eu/result/rcn/149876\\_en.html](http://cordis.europa.eu/result/rcn/149876_en.html) Accessed July 20th 2017

<sup>34</sup> Estimated Annual Economic Impacts from Harmful Algal Blooms (HABs) in the United States. Available at : <http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.693.5018&rep=rep1&type=pdf> Accessed July 20th 2017

<sup>35</sup> Marine researcher, specialising in algal blooms. Interview conducted on 22nd August 2017.

<b>Medium estimate</b>	1.7	3.3	6.0	65.4
<b>High estimate</b>	0.8	2.5	5.1	50.1

Table 20 - Copernicus total EU benefits for the three scenarios (EUR 2017, not discounted values) (Source: PwC analysis)

#### 4.1.5.4 Ice monitoring to support (winter) navigation/ship routing

Sea ice evolution is a complex and variable phenomenon. From a year to another, throughout a season or from one region to the other, sea ice conditions are completely different. The use of satellite imagery is therefore crucial to track these evolutions and support winter navigation. Copernicus is providing data and products on sea ice extent, thickness, concentration, motion and ridges in the Northern seas that enable the monitoring and forecasting of sea ice conditions through the publication of sea ice maps<sup>36</sup>. Since the launch of Sentinel-1 in 2014, it has become the main source of satellite imagery enabling this mapping<sup>37</sup>.

##### 4.1.5.4.1 Reduced cost of navigation through decreased fuel consumption, shorter transit times and faster routes

Satellite imagery have been used to improve navigation routes that icebreakers are supposed to make safe. Before the availability of satellite imagery, icebreakers used to rely on helicopters that would provide several pictures of the sea and detect potential ice charts to warn icebreakers. However, these helicopters had a cost and the reliability was not entirely guaranteed (e.g. no flight at night, limited speed making it possible for weather conditions to change before the icebreakers could be warned and react, etc.). As such, the more often satellite images are taken, the better the quality of the information provided will be. The benefits enabled by Copernicus are calculated as follows:



##### 4.1.5.4.2 Avoided ecological impact/marine pollution due to reduced CO<sub>2</sub> emissions from fuel combustion

The analysis relies on CO<sub>2</sub> emissions reductions due to decrease in fuel consumption from icebreakers and ship operators. Satellite imagery involved in fuel reduction, and thus CO<sub>2</sub> emissions reduction, is exactly the same as for the previous benefit. Indeed, it is because of the gain in time of 5 to 8 hours per journey enabled by Copernicus that fuel consumption is reduced. The benefits enabled by Copernicus are calculated as follows:



##### 4.1.5.4.3 Summary of ice monitoring to support (winter) navigation/ship routing benefits

Copernicus EU benefits – EUR M	2017	2025	2035	Cumulative (2017 – 2035)
<b>Low estimate</b>	2.6	28	84.6	735
<b>Medium estimate</b>	5.3	42.8	110.1	1,031

<sup>36</sup> CMEMS portal. (Online) Available at: <http://marine.copernicus.eu/training/education/ocean-parameters/sea-ice/> (Accessed: July 19th 2017)

<sup>37</sup> EARSC case study. (Online) Available at : <http://earsc.org/news/copernicus-sentinels-products-economic-value-study> (Accessed: July 19th 2017)

<b>High estimate</b>	10.3	78.5	198.3	1,874
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Table 21 - Copernicus total EU benefits for the three scenarios (EUR 2017, not discounted values) (Source: PwC analysis)

### 4.1.5.5 Maritime Navigation

Navigation plays an important role in maintaining and reinforcing the safety of cargo ships. Indeed, wind, waves and heavy weather conditions can greatly affect cargo ships' expeditions and jeopardise and or/delay their operations. By providing information on ocean wind fields, ocean wave spectra and surface radial velocity that can be exploited to feed marine forecast models, Copernicus participates to the identification of safer and faster routes for cargo vessels.

#### 4.1.5.5.1 Avoided loss of goods:

Cargo ships are often confronted with difficult sea and weather conditions, which, in some cases, may greatly endanger the containers carried on board. Information on ocean wind fields, ocean wave spectra and surface radial velocity provided by Copernicus can be exploited to build marine forecast models. By detecting and forecasting sea areas that would endanger carrying vessels on their journey, Copernicus enables the definition of safer maritime routes. The benefits enabled by Copernicus are calculated as follows:



#### 4.1.5.5.2 Fuel savings reached through optimised navigation routes:

Shipping companies have an economic interest in reducing the fuel consumption of their cargo ships fleet. The forecast of marine currents can enable cargo ships to use current routing for their voyage and therefore reduce their fuel consumption. Such identification of current routes is reached by the utilisation of meteorological and oceanographic data. Copernicus provides information on winds, waves and drifts, support currents modelling forecasts which can be exploited by shipping companies to define economical routes. The benefits enabled by Copernicus are calculated as follows:



#### 4.1.5.5.3 Summary of maritime navigation benefits

Copernicus benefits – EUR M	2017	2025	2035	Cumulative (2017 – 2035)
<b>Low estimate</b>	1.4	3.4	6.0	70.2
<b>Medium estimate</b>	3.5	8.4	17.0	181.3
<b>High estimate</b>	5.6	14.5	31.1	319.4

Table 22 - Copernicus total EU benefits for the three scenarios (EUR 2017, not discounted values) (Source: PwC analysis)

## 4.1.6 Disasters & geohazards

### 4.1.6.1 Fire detection and monitoring

By providing actors with forest fire information and fire danger indices, EFFIS supports them in taking necessary measures to reduce fire risks. Thus fire prevention and mitigation will be enhanced, and fire preparedness augmented. Mapping services provided by the Copernicus EMS will support the immediate response to fire suppression and the extraction of people if necessary. Copernicus mapping services also

provide risk and recovery maps that help actors assessing the damage extent and severity, assess the risk related to forest fires and build a recovery plan.

#### 4.1.6.1.1 Reduced environmental damages

The different varieties of land have different values to the ecosystem. This value comes from non-market services such as recreation, watershed, soil protection, biodiversity, pollination, etc. Different types of land are affected by fires: as such, the loss of forest does not have the same environmental consequences as the loss of artificial surfaces for instance. Copernicus has a double contribution in the fight against environmental damages caused by fires: first, the prevention and mitigation of fires and second, the preparedness and response to fires through mapping. The first activity is exclusively undertaken by EFFIS, whereas the second activity is undertaken both by EFFIS and by the Copernicus EMS mapping service.



#### 4.1.6.1.2 Reduced toxic emissions

By saving areas from burning, it is possible to avoid the release of several toxic emissions. Similarly to the previous benefit, Copernicus has a double contribution through its two services, EFFIS and the mapping service.



#### 4.1.6.1.3 Reduced economic damages in forestry

Besides environmental damages linked to toxic emissions and damages to the ecosystem, forest fires also have an economic impact on wood production and on hunting activities<sup>38</sup>. Economic damages of forest fires in Europe have already been estimated for a yearly average of EUR 2.7 B<sup>39</sup> in terms of forest reconstruction value after a fire.



#### 4.1.6.1.4 Summary of fire detection and monitoring benefits

Copernicus benefits – EUR M	2017	2025	2035	Cumulative (2017 – 2035)
<b>Low estimate</b>	304.0	331.6	438.8	7,238.3
<b>Medium estimate</b>	377.6	441.9	540.4	8,946.2
<b>High estimate</b>	451.3	492.1	642.0	10,654.2

Table 23 - Copernicus total EU benefits for the three scenarios (EUR 2017, not discounted values) (Source: PwC analysis)

<sup>38</sup> Di Fonzo M., P.M. Falcone, A.R. Germani, C. Imbriani, P. Morone, F. Reganati (2015). The Quantitative and Monetary Impacts of Forest Fire Crimes. Report compiled as part of the EFFACE project, University of Rome “La Sapienza”, www.efface.eu.

<sup>39</sup> San-Miguel-Ayanz and EFFIS Team, 2015. The European Forest Fire Information System

## 4.1.6.2 Flood monitoring and forecasting

Floods are the most recurring disasters in Europe and cause the highest number of victims and economic damages on yearly averages compared to any other disaster. Flood damages do not only consist in destroying property or land but also have long term effects. Floods leave people homeless and injured, cause disruptions in daily utilities such as electricity and water and can lead to the contamination of the drinkable water, causing more serious long term health problems. Knowing the danger of floods, identifying the vulnerabilities are crucial to put action plan in place, improve preparedness and accelerate recovery. By warning entities of flood risks before they occur, Copernicus Mapping services and EFAS (European Flood Awareness System) can play a direct role in flood mitigation.

### 4.1.6.2.1 Reduced economic losses (Economic benefit)

#### 4.1.6.2.1.1 Thanks to flood preparedness, prevention and mitigation (EFAS)

Several studies have been performed on the methods of reducing disaster risks, and the most efficient was found to be flood forecasting. Hence, EFAS provides the chance to prepare for the flood, evacuate the areas and take necessary measures. The value of economic damages can be reduced thanks to early warning. Resulting economic benefits are calculated as follows:



#### 4.1.6.2.1.2 Thanks to the support of on ground logistics and improved response (Copernicus mapping)

By providing on-demand Rapid Mapping services, Copernicus can deliver support to on ground response within the first hours or days of the flood occurrence. Risk and Recovery Mapping provides geospatial information supporting the preparation for flood risks or in planning recovery. These maps can be critical for assessing the extent of the damages, plan logistics, and locate evacuation areas. Overall they contribute (less than forecasting) to the reduction in economic losses due to floods. Benefits calculations are presented below:



### 4.1.6.2.2 Avoided fatalities and injuries in the population (Societal benefit)

#### 4.1.6.2.2.1 Thanks to flood preparedness, prevention and mitigation

Through procurement of flood forecasting and early warning, EFAS can increase awareness about areas of high risks and vulnerability, and therefore allows authorities to make better informed decisions favorable to flood risk reduction (adapted buildings, land planning, emergency plans), which, in case of flood, will prevent some fatalities and injuries to happen. Valuation coefficients are used to estimate the financial cost of fatalities and injuries (based on hospitalization cost and statistical value of life).<sup>40</sup>



<sup>40</sup> For more details on the methodologies behind the valuation coefficients, please refer to: PwC, 2015, Valuing corporate environmental impacts, PwC Methodology document.



#### 4.1.6.2.2 Thanks to the support of on ground logistics and improved response (Copernicus mapping)

In the last 5 years, the Copernicus Mapping services have been activated for certain flood event (adoption/contribution rate), resulting in improved response plans and strategies in case of floods event. Authorities have thus access to the general picture and can rescue people in endangered areas or identify key areas where help is most needed.



#### 4.1.6.2.3 Summary of Copernicus benefits for Floods monitoring and forecasting

Copernicus benefits – EUR M	2017	2025	2035	Cumulative (2017 – 2035)
<b>Low estimate</b>	125.2	682.8	2,156.3	18,122.6
<b>Medium estimate</b>	175.1	1,000.0	3,069.4	25,978.6
<b>High estimate</b>	225.0	1,317.3	3,982.6	33,834.6

Table 24 - Copernicus total EU benefits for the three scenarios (EUR 2017, not discounted values) (Source: PwC analysis)

### 4.1.6.3 Pandemic monitoring

In a global context where borders are more and more crossed, the spread of pandemics appears as a major risk which is difficult to control. The use of several Copernicus products that collect various sets of environmental data can support the monitoring of pandemics. Indeed, the models and studies assessing the different correlations between environmental factors and the development of infectious diseases are increasing their use of Earth Observation data to complement their research<sup>41</sup>. This is called tele-epidemiology and relies specifically on land use data, climate data or meteorological data. The analysis of data collected by Copernicus can support the surveillance of trends affecting the creation, development and spreading of diseases. However, it is currently not possible to monetize the benefits enabled by Copernicus on pandemic monitoring.

#### 4.1.6.3.1 Crop areas protected/livestock saved from the development of disease resulting in increase in revenue for farmers

The spreading of diseases among crops and plants, as well as among livestock is a major source of loss for farmers and can jeopardise food security. Depending whether the target is vegetal or animal, the diseases vary, but their consequences remain dramatic. Though it is currently not possible to monetize the impact of Copernicus on pandemics as a whole (notably because of a lack of maturity in Copernicus uptake), there are some examples demonstrating the relevance of Copernicus in supporting pandemic monitoring applications.

#### ***Use case: liver flukes***

*In the case of liver flukes, a bacteria that, once swallowed by herds, impact their dairy production, it has been possible to map Small Water Bodies (SWB) with Copernicus Sentinels, which are areas where snails that contaminate herds with the bacteria live. However, precise VHR optical data with a resolution lower than 5 meters are needed to go a step further than detecting SWB and map the snails' real habitat<sup>42</sup> as emphasized by the map of the Belgian app VECMAP developed in the frame of the EU FP7 GLOWORM project.*

41 Using Space to Fight Disease (Online). Available at: [http://eoeu.belspo.be/en/profs/Epidemio\\_A4\\_EN-small.pdf](http://eoeu.belspo.be/en/profs/Epidemio_A4_EN-small.pdf) (Accessed September 8th 2017)

42 R. Singh, K. Ranjan & H. Verma, 2015, "Satellite Imaging and Surveillance of Infectious Diseases", Journal of Tropical Diseases



## 4.1.7 Security

### 4.1.7.1 Control of Illegal, Unreported and Unregulated (IUU) fishing activities in the EU

Illegal, Unreported and Unregulated (IUU) fishing represents a threat for the fishing economy in Europe and has a negative impact on the marine ecosystem. The European fishing industry represents a substantial market with around 5 million tons of reported catch per year (mostly fished in large Atlantic) plus 1.2 million tons from aquaculture<sup>43</sup>, to which IUU fishing activities have to be added, representing around 15% additional catch. Through its contribution to the routine monitoring of fishing grounds, of fish cages and support to specific operations, EO supports the spotting of illegal activities and the identification of thieves, and therefore contributes to the progressive reduction of IUU fishing activities in Europe.

#### 4.1.7.1.1 Increased revenues for the fishing industry

IUU fishing implies the harvesting of livestock resources which abundance directly affects the revenues accessible to anglers. In addition to depriving regular anglers from their source of revenues, illegal fishing often relies on minimal cost approaches (exploitation of forbidden but more attractive fishing areas, forbidden fishing methods, etc.). Catches from IUU fishing can be sold at lower prices, generating unbalanced competition. The repression of IUU fishing activities dissuades illegal anglers, progressively leading to increased revenues for the industry. As it relies on a dissuasion effect rather than a direct mitigation (illegal catches seized cannot be saved and returned to sea when fishes are dead), the actual benefits for the industry materialise after few years, as the difference between the theoretical revenues with no IUU fishing fighting and the actual revenues. The benefits enabled by Copernicus are calculated as follows:



#### 4.1.7.1.2 Preservation of fish stock sustainability on the long term

The uncontrolled depletion of the ecosystem livestock appears more on the long term, as depending on the species, the reproduction cycle takes between 3 to 10 years. An over-exploitation of fish livestock implies a reduced stock to ensure the renewal of the species. This slower renewal leads to smaller amounts of resources in the future and maintains the level of fish in a low-value state. While illegal fishing has an immediate effect on industry revenues (each ton illegally fished is taken from regular fishing), this impact materialises on the long term, and characterises the ability of stocks to sustain, with all the consequences it implies. The benefits enabled by Copernicus are calculated as follows:



#### 4.1.7.1.3 Increased penalties perceived by MS for law infringements

The monitoring of IUU fishing leads to economic sanctions for the illegal fishers, inflicted and perceived by Member States. The contribution of Copernicus to IUU fishing monitoring leads to more opportunities to intercept fraudsters, therefore to additional sanctions. It should be noted that sanctions remain a point of heterogeneity between the Member States which do not all have the same levels of penalties<sup>44</sup>. The European Commission has identified some room for improvement in the rigor and harmonisation of the practices in term of law enforcement. The benefits enabled by Copernicus are calculated as follows:

<sup>43</sup> Eurostat, Fishery statistics, accessible at [http://ec.europa.eu/eurostat/statistics-explained/index.php/Fishery\\_statistics#Catches](http://ec.europa.eu/eurostat/statistics-explained/index.php/Fishery_statistics#Catches); European Commission, 2016, Facts and figures on the common fisheries policy

<sup>44</sup> European Commission, Communication to the Council and the European Parliament, Reports from Member States on behaviours which seriously infringed the rules of the Common Fisheries Policy in 2005

**Increased penalties perceived by MS**  
Valuation approach

Impact (EUR)

=

Contribution of Copernicus to  
IUU fishing spotting

X

Decrease of IUU fishing  
tonnage

#### 4.1.7.1.4 Summary of control of IUU fishing benefits

Copernicus benefits – EUR M	2017	2025	2035	Cumulative (2017 – 2035)
<b>Low estimate</b>	0.023	0.372	0.758	7.81
<b>Medium estimate</b>	0.048	0.575	1.04	11.5
<b>High estimate</b>	0.081	0.823	1.36	15.8

Table 25 - Copernicus total EU benefits for the three scenarios (EUR 2017, not discounted values) (Source: PwC analysis)

### 4.1.7.2 Maritime safety - Search & Rescue

The hostility of maritime environment implies high risks for lives involved in incidents at seas. Search & Rescue (S&R) missions are critical across both the detection phase to spot the vessels in distress and the intervention phase to rescue passengers. While S&R missions commonly refer to the rescue of vessels in regular maritime traffic, Europe also faces a particular situation with the important flow of migrants crossing the Mediterranean Sea. When considering the wider potential applications for EO, satellite images can support 3 aspects of S&R missions: location of vessels, support to S&R operations, and ship traffic information.

#### 4.1.7.2.1 Reduction of casualties in maritime disasters – Regular maritime traffic

A better response in case of a maritime incident can materialise in different manners, the most impactful one being the reactivity to commission rescue teams on-site, so the gain in efficiency enabled by satellite images can be reflected in additional lives saved. This approach attributes a monetary value to each life, which should not be seen as the value of the person, but as the economic footprint of each person in society, in the sense of the economic value generated by all the day to day activities of this person (work, spending, taxes, social activities etc.). The benefits enabled by Copernicus are calculated as follows:

**Reduction of casualties in maritime disasters – Regular maritime traffic**  
Valuation approach

Impact (EUR)

=

Contribution of  
Copernicus to S&R  
missions

X

Number of lives  
saved from  
maritime incidents

X

Statistical value of  
lives

#### 4.1.7.2.2 Reduction of casualties in maritime disasters – Refugees boats

The impact for refugees rescue missions, although measured on the same criterion (lives saved) is driven through slightly different levers than for regular traffic. The refugee crisis takes place in the Mediterranean Sea, mainly between Libya and the Italian and Greek coasts. EO contributes to the efficiency of operations by helping on vessel identification, by anticipating the migrant flows and feeding drifting models to spot lost vessels. If these levers are quite different from the regular vessels missions, the outcome remains the same, meaning an increase in lives saved. The benefits enabled by Copernicus are calculated as follows:

**Reduction of casualties in maritime disasters – Refugees boats**  
Valuation approach

Impact (EUR)

=

Contribution of  
Copernicus to S&R  
missions

X

Number of refugees  
lives saved from  
maritime incidents

X

Statistical value of  
lives

#### 4.1.7.2.3 Summary of maritime safety – search & rescue benefits

Copernicus benefits – EUR M	2017	2025	2035	Cumulative (2017 – 2035)
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<b>Low estimate</b>	0	23.6	68.6	592.6
<b>Medium estimate</b>	5.4	52.8	125.8	1,195.1
<b>High estimate</b>	20.6	93.4	196.7	2,019.9

Table 26 - Copernicus total EU benefits for the three scenarios (EUR 2017, not discounted values) (Source: PwC analysis)

### 4.1.7.3 Oil pollution monitoring

The activities considered in this chapter include pollution from Oil & Gas (O&G) platforms (fixed structures) and from ships, typically oil tankers, which generate pollution either from accidents or from voluntary de-ballasting. The Copernicus Maritime Surveillance service contributes to pollution monitoring through 3 main outputs: pollution detection, specific tasking for operational support and support to pollution response.

#### 4.1.7.3.1 Reduced economic damages due to oil spills

Following an oil spill, the consequences include several types of damages on the near-by areas, with economic consequences on commercial activities. Among the activities most directly impacted, fisheries can lose part of their production in addition to a negative impact on their image leading to reduced selling price. The tourism sector suffers from reduced volume of tourists on the coast, and the maritime transport undergoes financial consequences as routes may be disturbed, imposing longer paths and delays. In addition, the clean-up operations and compensations linked to oil slicks imply substantial expenses for public authorities. The economic damages also include the value of the oil lost that cannot be exploited by O&G companies. The benefits enabled by Copernicus are calculated as follows:



#### 4.1.7.3.2 Reduced environmental damages due to oil spills

Following an oil spill, the consequences include several types of damages on the near-by areas, with environmental consequences, mostly on the ecosystem of the polluted area. The valuation of such impact is not straightforward, and is achieved by the Contingent Valuation method (used for the Prestige disaster as well as for the Exxon Valdez disaster). The benefits enabled by Copernicus are calculated as follows:



#### 4.1.7.3.3 Summary of oil pollution monitoring benefits

<i>Copernicus benefits – EUR M</i>	2017	2025	2035	Cumulative (2017 – 2035)
<b>Low estimate</b>	31.0	23.7	18.8	439.9
<b>Medium estimate</b>	41.6	31.2	24.7	582.0
<b>High estimate</b>	53.7	39.7	31.3	741.5

Table 27 - Copernicus total EU benefits for the three scenarios (EUR 2017, not discounted values) (Source: PwC analysis)

### 4.1.7.4 Law enforcement and international crime

The role of the Copernicus Security service is directly related to law enforcement, support to customs and fight against cross-border crime. These activities include both the repression of goods trafficking (counterfeit goods,

drugs, weapons, stolen vehicles) and the fight against Trafficking in Human Being (THB), a growing concern in Europe as the number of victims increases. European borders, both at sea and on land, are a control limit where illegal goods and THB victims are smuggled into the EU. Traditional controls by customs are not sufficient alone, and they are completed by surveillance means at sea (detection and tracking of suspicious vessels) and at land (monitoring of cross border crimes and unauthorised border crossings) to enable anticipating these illegal activities and increase the efficiency of interceptions.

#### 4.1.7.4.1 Increased interceptions of illegal goods

The amount of illegal goods intercepted at the border is an indicator of the law enforcement activities of MS. Illegal goods include: counterfeit goods, drugs and stolen vehicles. The impact from illegal weapons seizures remains very limited at EU borders. Consequently to less drugs being consumed in the EU, less addictions and acute health issues have to be treated by public healthcare structures in MS. The effect on healthcare systems is not immediate however, as many health issues are triggered by recurrent consumption or long term exposure. The benefits enabled by Copernicus are calculated as follows:



#### 4.1.7.4.2 Increased interceptions of victims of Trafficking in Human Beings

Over the past decades, human mobility around the world has continuously developed, as illustrated by the increase in number of international migrants. Although most of the migrants are not victims of trafficking, there is a correlation between the flows of migration and the amount of people victim of THB. The main categories of exploitation for victims of THB are sexual exploitation and forced, followed by organ removal, child soldiers, forced marriage, forced begging or selling of children. The benefits enabled by Copernicus are calculated as follows:



#### 4.1.7.4.3 Summary of law enforcement and international crime benefits

<i>Copernicus benefits – EUR M</i>	2017	2025	2035	Cumulative (2017 – 2035)
<b>Low estimate</b>	51.4	267.2	628.2	6,446.7
<b>Medium estimate</b>	111.4	403.8	794.3	8,983.6
<b>High estimate</b>	200.4	556.5	976.8	11,859.1

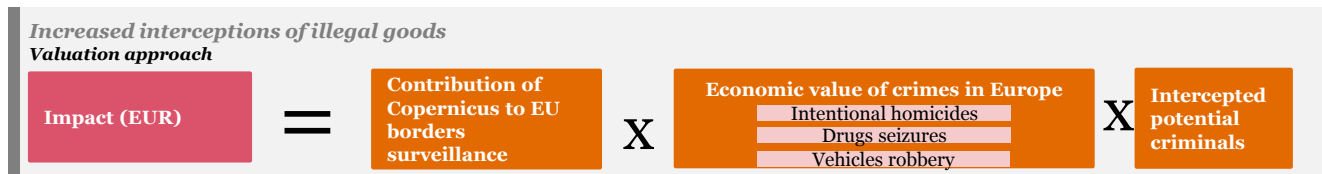
Table 28 - Copernicus total EU benefits for the three scenarios (EUR 2017, not discounted values) (Source: PwC analysis)

### 4.1.7.5 EU borders surveillance

As part of Copernicus, Frontex coordinates operational and EU measures to respond to exceptional situations at the external borders. Operational activities differ between sea (detection and tracking of migrants and suspicious vessels, monitoring of points of departure and intelligence validation) and land (change detection and analysis, provision of environment information, intelligence validation and monitoring of crisis situation) borders surveillance by the nature of the environment, but one of the main goals is mainly oriented on the control of inbound immigration flows.

#### 4.1.7.5.1 Security improvement through EU borders surveillance

In the current context of security concerns in European MS and growth of terrorist activities, borders become a more and more strategic point to mitigate EU crime and prevent external threats to reach MS. The valuation of such control is achieved through the potential impact of suspicious profiles on EU criminality. Depending on the reason for denial, the profile can be estimated more or less risky with respect to the average crime rate. The benefits enabled by Copernicus are calculated as follows:



#### 4.1.7.5.2 Summary of EU borders surveillance benefits

Copernicus benefits – EUR M	2017	2025	2035	Cumulative (2017 – 2035)
<b>Low estimate</b>	0.1	0.9	1.3	16.5
<b>Medium estimate</b>	0.3	1.1	1.6	21.6
<b>High estimate</b>	0.5	1.5	1.9	27.4

Table 29 - Copernicus total EU benefits for the three scenarios (EUR 2017, not discounted values) (Source: PwC analysis)

### 4.1.7.6 Baseline summary

This section brings together all the benefits enabled by the Copernicus D&I over the period 2017 – 2035 for the baseline option (option 1). The figure below summarises all the benefits (not discounted) for intermediate users and end-users over the period 2017 – 2035 for the three scenarios under scrutiny.

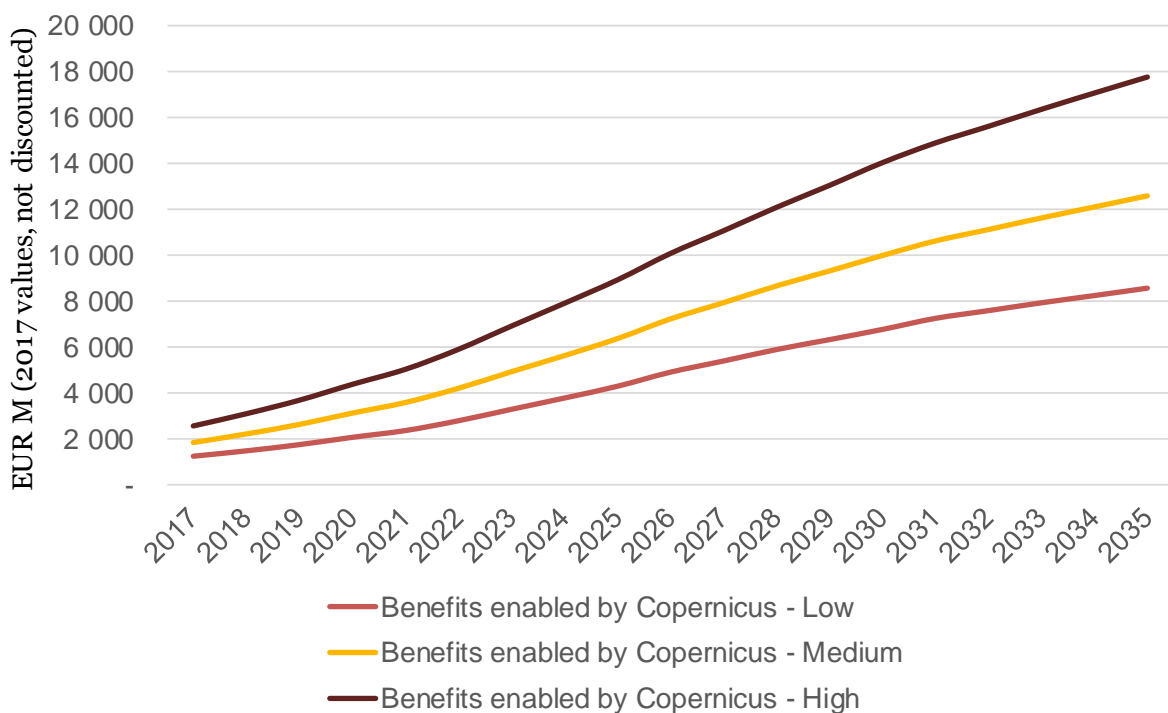


Figure 2 - Evolution of the overall baseline benefits enabled by Copernicus D&I for the three scenarios under scrutiny (Source: PwC analysis)

As a result, the total not discounted benefits linked to Copernicus are expected to amount to:

<i>Copernicus EU benefits – EUR M</i>	2017	2025	2035	Cumulative (2017 – 2035)
<b>Low estimate</b>	1,280.0	4,326.4	8,599.6	92,556.0
<b>Medium estimate</b>	1,875.6	6,400.0	12,618.6	136,320.7
<b>High estimate</b>	2,598.8	8,956.0	17,792.5	190,989.9

*Table 30 - Copernicus total EU benefits of option 1 for the three scenarios (EUR 2017, not discounted values) (Source: PwC analysis)*

## 4.2 Comparison with Evolution option N°2: Shutdown

Option 2 illustrates the scenario where the Copernicus programme is stopped after 2030 with a progressive shutdown after 2027, without renewal of Sentinels spacecraft. Option 2 ends in 2030 with the transfer of ownership of flying satellites (Sentinels), and the shutdown and dismantling of existing Copernicus core services.

The assessment of benefits is based on the baseline option's benefits assessed in the previous chapter, with a specific user uptake due to the peculiarity of the shutdown option. Indeed, for modelling requirements, it is assumed that the shutdown of Copernicus Programme would be announced in 2025. Before this date the benefits will be the same as assessed in the baseline option. They follow the classic S-shaped curve which illustrates the user-uptake and which is intrinsically linked to the continuity of the Copernicus programme (long-term, ensured, free and open access to data). Announcement of the shutdown should be followed by a modification in users' behaviour that may start looking for other data sources (61% Copernicus users consider that continuity is the most important factor to support innovation derived from Copernicus D&I<sup>45</sup>), resulting in a very negative impact on the user uptake. Benefits will drastically decrease as of the announcement, following an inverse S-shaped curve. This inverse S-shaped curve is used to model the decrease of Copernicus contribution in all modelled impacts, starting from 2025 (announcement) leading to a complete disappearance of Copernicus D&I benefits in 2030 (shutdown date).

<i>Copernicus benefits – EUR M</i>	2017	2025	2030	Cumulative (2017 – 2030)
<b>Low estimate</b>	1,279.0	4,110.0		30,034.7
<b>Medium estimate</b>	1,875.6	6,081.0	0	44,612.4
<b>High estimate</b>	2,598.8	8,508.2		62,334.9

*Table 31 - Copernicus total benefits of option 2 for the three scenarios (EUR 2017, not discounted values) (Source: PwC analysis)*

<i>Copernicus benefits – EUR M</i>	Loss of benefits for society (2025 – 2030)	Additional benefits that could have materialised (2031 – 2035)
<b>Low estimate – Difference between option 1 &amp; 2</b>	22,780.1	39,741.2
<b>Medium estimate – Difference between option 1 &amp; 2</b>	33,492.6	58,215.7
<b>High estimate – Difference between option 1 &amp; 2</b>	46,815.2	81,839.9

<sup>45</sup> European Commission, 2016. Boosting the growth of European EO companies. Survey analysis. Brussels, Belgium.



Table 32 - Comparison of option 1 and 2 for the medium scenario (EUR 2017; not discounted values) (Source: PwC analysis)

### 4.3 Comparison with Evolution option N°3: Environmental

Option 3 illustrates the scenario where the current scope of environmental services is extended by adding new capabilities to the Sentinel fleet and potential new in-situ data. It is composed of four different modules targeting different areas:

- 1) Anthropogenic CO2 emissions monitoring;
- 2) Arctic environment and snow evolution monitoring;
- 3) Thermal InfraRed (TIR);
- 4) Hyperspectral.

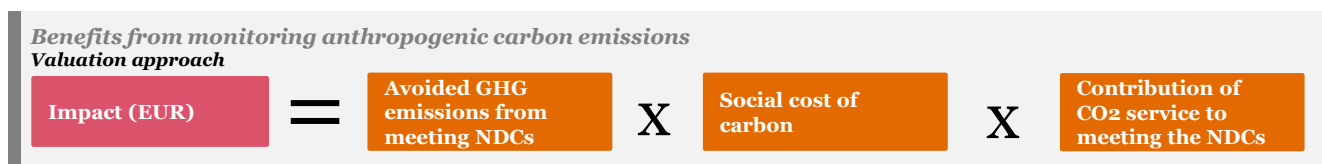
At the time of writing this report, these four modules were being analysed and no concrete decisions had been taken on the exact scope of each of these options (spatial resolution, temporal resolution, and geographical coverage). The benefit assessments of these options need to be taken as the assessment of a potential order of magnitude rather than a precise assessment, due to scarcity of information on these potential evolution options.

Two different types of methodologies have been used to monetize the benefits brought by Option 3: if the new capability brought by Copernicus enables benefits for new applications that Copernicus did not contribute to before, the methodology is presented per benefit below; if the new capability enables to improve the benefits of an application that Copernicus already contributed to, the approach used to quantify the benefits is based on the re-evaluation of Copernicus' contribution for each impact to which a new or enhanced capability would be relevant: we assess to what extent the new capability can remove the current limitations, reinforce the service by meeting additional users' requirements, and enhance the contribution of Copernicus to the benefit. The methodology is not presented below as it is similar to the one used for the baseline option.

#### 4.3.1.1 Option 3A - Anthropogenic CO2 emissions monitoring

The anthropogenic CO2 emissions monitoring option under a dedicated Sentinel mission will contribute to elaborate an operational capacity to monitor and to verify anthropogenic CO2 emissions. The associated space component intends to fill up an existing gap within the fleet of the current Copernicus satellites. The Copernicus programme offers the appropriate frame to develop such a CO2 service. It will be complemented by any useful and relevant in-situ datasets and ancillary information as well. The ultimate objective is thus to propose an information system dedicated to policy makers regarding the impact and evolutions of the international agreements about CO2 concentrations and trends and the national actions that have been agreed upon by all parties having signed the Paris agreement.

The current Copernicus C3S and CAMS services will join forces to monitor anthropogenic CO2 from space from 2025. The planned C3S/CAMS service would not in itself lead to improved carbon reduction strategies, but would support these by providing policymakers with actionable information at various stages of the policy cycle<sup>46</sup>. Our approach assumes that CO2 service will provide improved information on greenhouse gas inventories, which reduces errors and uncertainties and improves policy decision making, which creates economic value through more effective climate mitigation policy<sup>47</sup>. However, as numerous other factors affect whether countries will meet NDC targets, Copernicus contribution is assumed to be low. As this service could reduce mitigation costs, our model aims at assessing this particular aspect. The benefits enabled by Copernicus are calculated as follows:



<sup>46</sup> European Commission, 2015. Towards a European Operational Observing System to Monitor Fossil CO2 emissions.

<sup>47</sup> Cooke et al., 2016. Using the social cost of carbon to value earth observing systems.



#### 4.3.1.1.1 Summary of additional benefits brought by the anthropogenic CO2 emissions monitoring option

Impact driver	Zone	Scenario	Gain
Monitoring anthropogenic carbon emissions	EU	Low	EUR 1.95 B
		Medium	EUR 5.78 B
		High	EUR 9.50 B

Table 33 - Copernicus total EU benefits for the three scenarios (EUR 2017, not discounted values) (Source: PwC analysis)

### 4.3.1.2 Option 3B - Arctic environment and snow evolution monitoring

This option is composed of two main enhancements of the services currently offered by the Copernicus programme: first the improvement of Arctic environment monitoring; second the improvement of snow monitoring activity over European mountain areas. Indeed, conservation and management of the Arctic region is becoming a key priority area for Europe, and is part of the strategic goals of the European Union over the next decade<sup>48</sup>. Besides, the measurement of snow parameters are essential for several sectors such as hydrology, climatology, meteorology or water resources management. Such an option would rely on an expansion mission including one or more satellites to fly in parallel with the current constellation (the first satellite should then be launched between 2025 and 2030).

With the melting of the Arctic sea ice, shipping and off-shore operations are expected to increase in this region. Three key impact areas have been monetised:

- Maritime transport: Ice monitoring to support shipping navigation in the Arctic region and adjacent seas

#### Benefits from ice monitoring in the Arctic Valuation approach



- Security: Support search and rescue in northern European countries and Arctic region

#### Benefits from search and rescue in the Arctic Valuation approach



- Pollution: Reduce oil spills in the Arctic from off-shore operations

#### Benefits from reduced oil spills in the Arctic Valuation approach



The other benefit that can be monetised is related to the improved profitability of the hydropower sector. This benefit is enabled by the improvement of snow monitoring, as melted snow can be used for filling the hydropower facilities' reservoirs. This brings additional gain to the previously mentioned benefit "improved profitability in the hydropower sector".

<sup>48</sup> European Commission, 2016. An integrated European Union policy for the Arctic. Joint communication to the European Parliament and the Council. Brussels, Belgium.

#### 4.3.1.2.1 Summary of additional benefits brought by the Arctic environment and snow evolution monitoring option

Impact driver	Impact/benefit	Scenario	Gain
<b>Arctic monitoring</b>	Ice navigation in the Arctic	Low	EUR 272.6 M
		Medium	EUR 371.2 M
		High	EUR 670.0 M
	Search & rescue in the Arctic	Low	EUR 76.2 M
		Medium	EUR 127.8 M
		High	EUR 192.5 M
	Oil pollution in the Arctic	Low	EUR 324.3 M
		Medium	EUR 426.7 M
		High	EUR 540.5 M
<b>Snow Monitoring</b>	Improve profitability in the hydropower sector	Low	EUR 29.8 M
		Medium	EUR 65.0 M
		High	EUR 132.3 M
<b>Total benefits for option 3B</b>		Low	EUR 702.8 M
		Medium	EUR 990.6 M
		High	EUR 1,535.2 M

Table 34 - Copernicus total EU benefits for the three scenarios (EUR 2017, not discounted values) (Source: PwC analysis)

### 4.3.1.3 Option 3C - Thermal Infrared capability

This option aims to complement Sentinel observation capabilities with an enhanced Thermal InfraRed (TIR) capability over land and coastal areas. This new capability is expected to be launched in 2026 and operational by 2027. The Copernicus programme already provides thermal information over land and water through contributing missions such as Landsat 8 and Sentinel missions such as Sentinel-3A and 3B. However, these existing thermal infrared capabilities will not be sufficient enough to answer growing needs for surface temperature data in critical domains and applications. The key target of the Option 3C mission is to monitor evapotranspiration at European level and analysing the variability of Land Surface Temperature (LST) to support agriculture. Enhanced Thermal InfraRed capability could also support mapping and monitoring of soil composition (mineralogy and organic matter).

Therefore, introduction of the new enhanced TIR capabilities within the Copernicus products portfolio, could affect the following impact drivers and certain of their derived benefits.

- Water resources management as far as the irrigation management for agriculture is concerned;
- Crops monitoring concerning the Food security issue (water stress detection);
- Urban Monitoring when it comes to Urban Heat Islands mitigation;
- Fire detection and monitoring, concerning both environmental consequences and economic ones;
- Pandemic monitoring for the protection of crops and livestock against disease.

As these only represent improvements of already existing benefits, the methodology used for the calculation of benefits is the same as the one presented in the baseline, but takes into account the new additional capability of Copernicus.

#### 4.3.1.3.1 Summary of additional benefits brought by the Thermal Infrared capability option

Impact driver	Impact/benefit	Scenario	Gain
<b>Water resources management</b>	Improve agriculture productivity through better irrigation management	Low	EUR 48.3 M
		Medium	EUR 68.9 M
		High	EUR 98.8 M
<b>Crop monitoring</b>	Improve food security	Low	EUR 353.2 M
		Medium	EUR 412.5 M
		High	EUR 471.8 M
<b>Urban area monitoring</b>	Reduced mortality rate caused by Urban Heat Islands	Low	EUR 60.4 M
		Medium	EUR 113.7 M

<b>Fire detection and monitoring</b>	Reduced environmental damages	High	EUR 176.9 M
		Low	EUR 3.2 M
		Medium	EUR 9.6 M
	Reduced toxic emissions	High	EUR 16.0 M
		Low	EUR 46.4 M
		Medium	EUR 79.8 M
	Reduced economic losses	High	EUR 113.2 M
		Low	EUR 192.9 M
		Medium	EUR 331.7 M
<b>Pandemic monitoring</b>	Crop areas protected/livestock saved from the development of disease	High	EUR 470.5 M
		Low	EUR 60.4 M
		Medium	EUR 113.7 M
<b>Total benefits for option 3C</b>		High	EUR 176.9 M
		Low	EUR 820.4 M
		Medium	EUR 1,290.1 M
		High	EUR 1,848.2 M

Table 35 - Copernicus total EU benefits for the three scenarios (EUR 2017, not discounted values) (Source: PwC analysis)

### 4.3.1.4 Option 3D - Hyperspectral capability

The aim of this option would be to provide hyper spectral resolution over land and coastal areas in support of natural resources management. The hyperspectral mission would more specifically enable to add several new spectral bands compared to what's already available on the Sentinel-2 multispectral mission. ESA's PROBA1/CHRIS has stressed the utility of hyper spectral imaging through a seventeenth year of operation (launch in 2001, still operational), demonstrating potential value for mining, geology, forestry, agriculture; civil engineering; water quality and environmental management.

Hyperspectral imagery is composed of a large number of narrower bands obtained by the use of an imaging spectrometer instrument. Hyperspectral sensors equipped on board of a potential Sentinel mission would be capable of providing 20-30 resolution images in several hundreds of narrow bands. Such a feature should enable the direct and indirect distinction of surface quantities: it could support the identification and characterisation of soil composition, of wetlands properties and of coastal regions constituents.

The impact drivers and derived benefits affected by the entry into operation of this option are presented below.

- Forestry Management and protection, for the benefit "Improve and preserve forest ecosystems and green infrastructures"
- Crop Monitoring – support to agriculture, for the benefit "Improved agriculture profitability and cost efficiency"
- Wetlands monitoring, as Hyperspectral enhances the benefit of EO linked to Wetlands ecosystems restoration
- Mining and quarrying: minerals and raw materials extraction, for the support of the exploration and extraction of mines as well as the pollution resulting from mining activities.

As these only represent improvements of already existing impacts, the methodology used for the calculation of benefits is the same as the one presented in the baseline, but takes into account the new additional capability of Copernicus.

Nevertheless, if hyperspectral is expected to bring significant benefits in various sectors, it is not always possible to exploit the data gathered by the sensor. It seems clear that hyperspectral instruments will play an important role for the next generation of optical satellite sensors, but the cost and complexity of the instruments, computers processing and algorithms required to analyse hyperspectral data, can hinder the adoption of the technology<sup>49</sup>.

#### 4.3.1.4.1 Summary of additional benefits brought by the Hyperspectral capability option

Impact driver	Impact/benefit	Scenario	Gain
Forestry management	Improve restoration of wetlands	Low	EUR 328.3 M

49 Hyperspectral analysis set to expand incoming decade, IHS Jane's Military & Security Assessments Intelligence Centre, 2017

<b>&amp; protection</b>	ecosystems	Medium	EUR 428.5 M
		High	EUR 528.8 M
<b>Crops Monitoring</b>	Improved agriculture profitability and cost efficiency	Low	EUR 84.7 M
		Medium	EUR 161.1 M
<b>Wetlands monitoring</b>	Improve and preserve forest ecosystems	High	EUR 255.8 M
		Low	EUR 375.3 M
<b>Mining and quarrying</b>	Minerals and raw materials extraction	Medium	EUR 552.0 M
		High	EUR 730.7 M
<b>Total benefits for option 3D</b>		Low	EUR 64.1 M
		Medium	EUR 96.2 M
		High	EUR 128.2M
		Low	EUR 852.3 M
		Medium	EUR 1,238.7 M
		High	EUR 1,643.4 M

Table 36 - Copernicus total EU benefits for the three scenarios (EUR 2017, not discounted values) (Source: PwC analysis)

## 4.4 Comparison with Evolution option N°4: Security

In the current context, security stakes for Europe, both internally and with regards to the world, are increasingly important and complex. Among the priorities of Europe External Action presented in the Global Strategy for the EU's Foreign and Security Policy, the security of the Union is more and more challenging to ensure, with still higher needs to remain resilient to the Middle East and North Africa regions. The management of conflicts demands a deeper cooperation both between MS and with 3<sup>rd</sup> countries, requiring integrated approaches to solve conflicts. The development of the security component of Copernicus is a lever to bring an answer to these types of challenges.

The characterisation of option 4 revolves around the following features that must be made accessible to EU security actors:

- Higher spatial resolution over wide areas:
- Guaranteed access to tasking (i.e. crisis management)
- Near-real time data

In addition to these criteria, collaborations within the Copernicus programme and horizontal integration of Copernicus data with other initiatives could also play an important role in the improvement of the Security service<sup>50</sup>.

Hence the impact drivers and derived benefits affected by the entry into operation of this option are presented below.

- Control of IUU fishing
- Maritime safety – Search and Rescue
- Oil pollution monitoring
- Law enforcement and international crime
- EU borders surveillance

As these only represent improvements of already existing impacts, the methodology used for the calculation of benefits is the same as the one presented in the baseline, but takes into account the new additional capability of Copernicus, calculated with the methods presented above.

### 4.4.1.1 Summary of additional benefits brought by the Security option

Impact driver	Impact/benefit	Scenario	Gain
<b>Security</b>	Control of IUU fishing	Low	EUR 14.8 M
		Medium	EUR 16.6 M
		High	EUR 18.5 M
	Maritime safety – Search & Rescue	Low	EUR 1,747.8 M

<sup>50</sup> Stakeholder consultation

	Oil pollution monitoring	Medium	EUR 2,822.8 M
		High	EUR 4,171.4 M
		Low	EUR 472.7 M
		Medium	EUR 505.5 M
		High	EUR 526.3 M
		Low	EUR 18,753.7 M
	Law enforcement and international crime	Medium	EUR 22,160.0 M
		High	EUR 25,335.0 M
		Low	EUR 32.9 M
	EU borders surveillance	Medium	EUR 39.0 M
		High	EUR 44.8 M
		Low	EUR 21,021.9 M
<b>Total benefits for option 4</b>	Medium	EUR 25,544.0 M	
	High	EUR 30,096.0 M	

Table 37 - Copernicus total EU benefits for the three scenarios (EUR 2017, not discounted values) (Source: PwC analysis)

## 5 Conclusion

The study has analysed the different options under scrutiny for this impact assessment in support of the future EC impact assessment for the evolution of the Copernicus programme.

**The present study focuses only on the impacts of the utilisation and exploitation of Copernicus D&I, and its spillovers on the wider European society.** Benefits are split between intermediate users and end-users benefits, but the study **does not take into account the cost of the options under scrutiny.** Moreover, this report **does not take into account the GDP impact of the Copernicus programme**, including **upstream revenues** attributed to the **development of the infrastructure** (space manufacturing, ground segment manufacturing) and **downstream revenues attributed to services development and services operation.**

The three evolution options were analysed with comparison to the baseline option (Continue the Copernicus programme), highlighting additional benefits in the case of option 3 (Extend Environmental Service) and option 4 (Extend Security Service) and a reduction of benefits in the case of option 2 (Shutdown option)<sup>51</sup>.

Shutdown option (option 2) presents a net loss of benefits when compared with the baseline option for the period 2025 – 2030. The announcement of shutdown is expected to lead a strong behavioural change in intermediate and end-users, pushing them to turn to alternatives options. After this period (2031 – 2035), additional benefits would be lost when compared to the baseline option.

The sum of all the benefits derived from Copernicus D&I for intermediate and end-users over the period 2017 – 2035 for the pessimistic scenario is illustrated in the chart below for all the options under scrutiny.

<sup>51</sup> The assessment of the shutdown focuses on the benefits derived from Copernicus D&I but counterfactuals and alternatives solutions can potentially be found by intermediate and end-users to limit the loss of benefits. Our assessment does not take into account such possibility of adaptation.

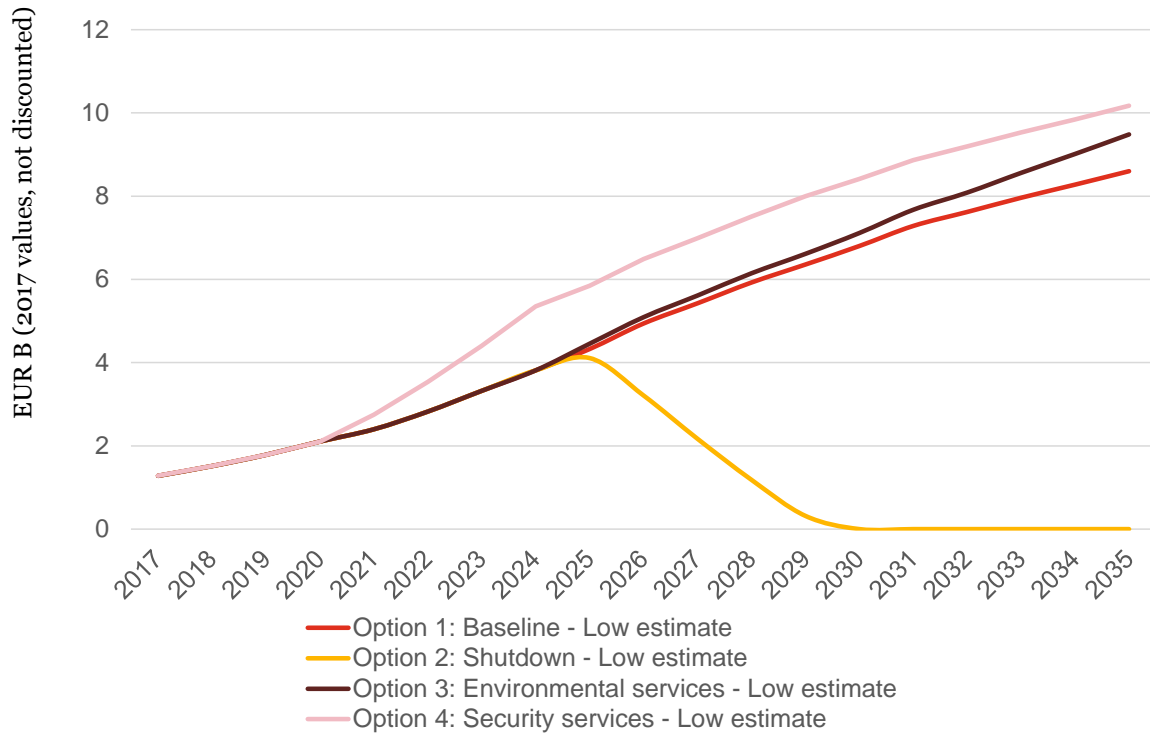


Figure 3 - Copernicus D&I benefits for all the options over the period 2017–2035 – Low estimate (Source: PwC analysis)

As for the average scenario, the evolution of benefits illustrated in the chart below:

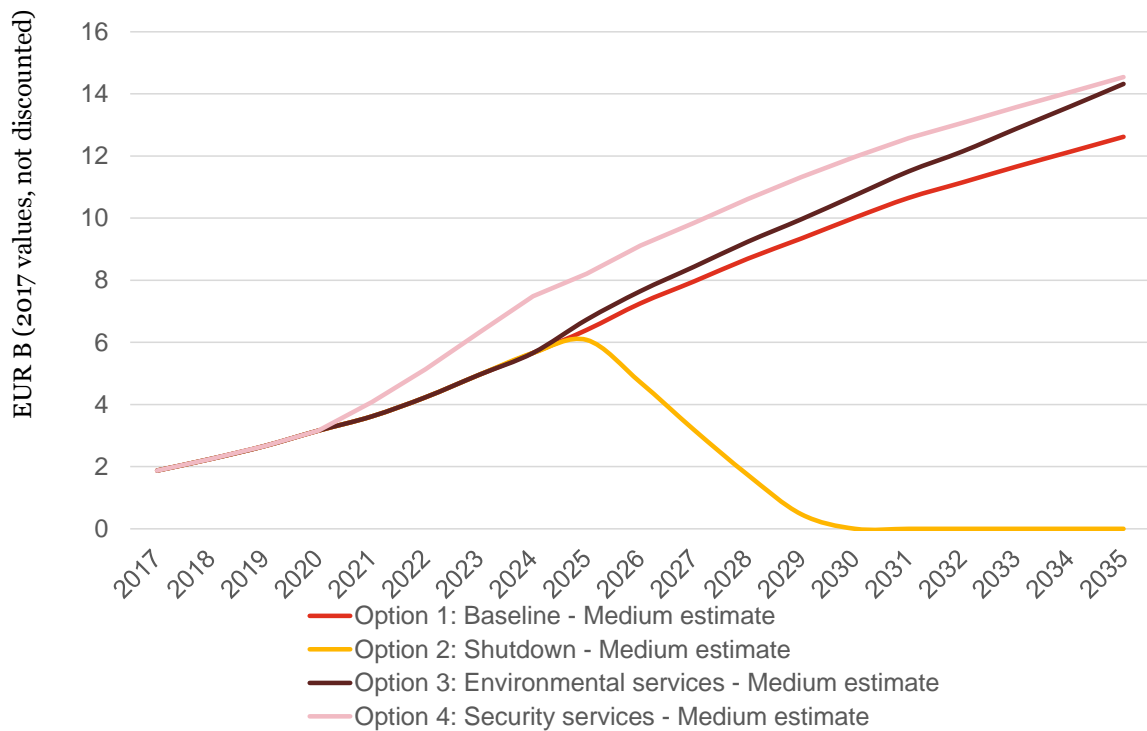


Figure 4 - Copernicus D&I benefits for all the options over the period 2017–2035 – Medium estimate (Source: PwC analysis)



For the optimistic scenario, the benefits derived from Copernicus D&I over the period 2017 – 2035 are presented in the chart below:

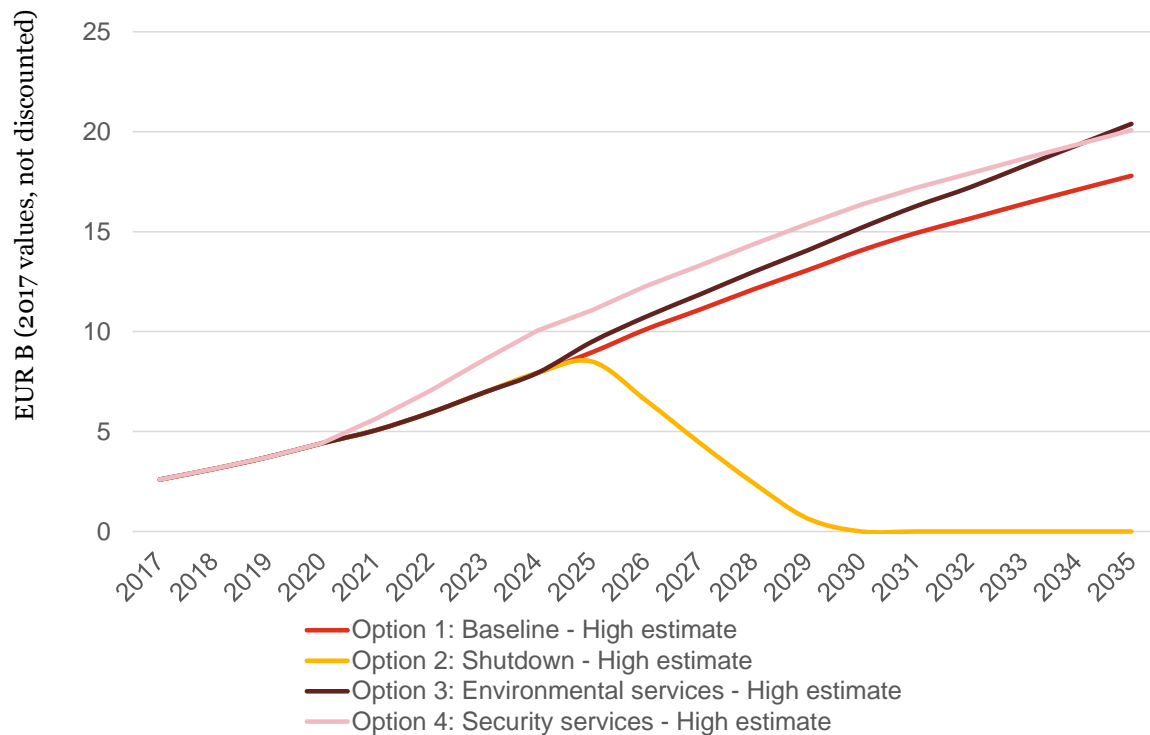


Figure 5 - Copernicus D&I benefits for all the options over the period 2017–2035 – High estimate (Source: PwC analysis)

The total global results of the all scenario (2017 values) are presented in the table below for EU only benefits. The benefits displayed for option 3 and 4 are additional to baseline option benefits.

Cumulative benefits – EUR B	Not discounted			Discounted		
	Low estimate	Medium estimate	High estimate	Low estimate	Medium estimate	High estimate
<b>Option 1 (Baseline)</b>	92.6	136.3	191.0	59.5	87.8	122.9
<b>Option 2 (Shutdown)</b>	30.0	44.6	62.3	23.8	35.4	49.5
<b>Option 3 (Enhanced environmental services)</b>	4.3	9.3	14.5	2.4	5.3	8.3
<b>Option 4 (Enhanced security Service)</b>	21.0	25.5	30.1	13.4	16.3	19.2

Table 38 - Copernicus total cumulative benefits for the three scenarios (Source: PwC analysis)