Study to examine the socio-economic impact of Copernicus in the EU

Report on the Copernicus downstream sector and user benefits

Written by PwC
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EUROPEAN COMMISSION

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Key findings

Historically one of the first domains to exploit EO, **agriculture** is the market in which Copernicus is expected to have the largest impact, especially through precision farming. Intermediate users in the value chain have various profiles, from start-ups and SMEs to large companies through purely scientific players. This is also the market with the highest penetration rate for Copernicus data, which already represents about 13% of the EO data exploited in the sector. Though not quantified here, the contribution of Copernicus to farmers' business can be expected to be substantial, given the importance of EO to precision farming technologies.

In some countries, **forests** are mainly owned either by public entities, while in others the ownership is mainly in private hands. As in agriculture, Copernicus intermediate users have a range of profiles, and Copernicus represents a substantial share of the EO data exploited, estimated at around 12% on average. End users are mostly public bodies and there are few commercial applications that exploit forestry EO-based products, making it difficult to put a value on end user benefits.

Urban Monitoring offers a wide range of applications for EO and hence for Copernicus. Intermediate users are mainly SMEs, working in a well-developed market of which Copernicus already represents about 10% of the EO data exploited. Urban Monitoring products are expected to benefit from the high growth of smart cities markets, and hence the influence of Copernicus is likely to continue to increase. The majority of end users are local authorities, which often face budget constraints that limit the speed with which they can adopt innovative products such as EO, but there are encouraging trends.

For **natural disasters insurance**, the benefits of intermediate users from Copernicus are estimated to be low as a gap still exists between the very specific needs of (re)insurers and the available EO products on the market. The result is either that EO raw data are handled in-house by end users who can afford the infrastructure, or that satellite images are not used at all, because they are regarded as a non-critical source of data. Index products represent a potential market for intermediate users, but the Copernicus constellation has not been in place long enough to be exploited. End user benefits have the potential to be much higher, given the very large amounts involved in natural disaster insurance. However the substantial variation observed between (re)insurers with regard to their adoption of Copernicus to date makes it difficult to give an assessment of the precise overall value.

Ocean Monitoring applications for EO are diverse, and involve various types of stakeholders. Intermediate users include private actors from micro-companies to large companies, public authorities, scientific laboratories or research centres. End users are also both public entities and private actors such as fish farmers and cooperatives. The rapidly-changing environment requires near real-time EO data, and so the penetration of Copernicus data is quite low at present, around 6%. Sentinel-3 is expected to raise substantially the benefits of Copernicus to ocean monitoring applications.

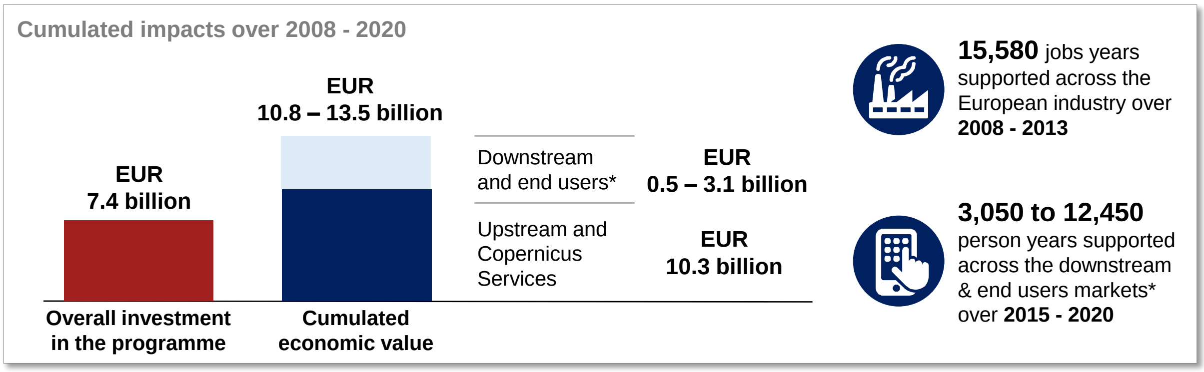
Oil & Gas is a commercially oriented value chain, and EO is mostly exploited in the upstream activities of O&G companies. Intermediate users generate substantial revenues based on Copernicus data, in the form of GIS products rather than pure EO data. End user benefits can be expected to be much higher given the large markets involved. The recent drop in the oil price curbed the willingness of O&G companies to invest in EO capabilities, but this should improve in the coming years.

Actors in the **Renewable energies** value chain exploit EO data particularly for biomass and solar energy. Commercial applications are relatively new for intermediate users. The total EO market represents less than EUR 23 million, of which Copernicus represents 10% of the revenues. End user benefits are estimated to be low compared to the EUR 130 billion European market for renewable energies, due to the limited part of the value chain impacted by EO and the low share of the Copernicus contribution in EO data, reckoned to be between 0.001% and 0.1%.

Air Quality information and applications only recently started to exploit EO data, being traditionally based on meteorological data, statistics and measurements. Intermediate users are mostly environmental and meteorological agencies, or publicly-funded organisations. End users' needs tend to be addressed directly by the public sector, as individuals do not demonstrate any willingness to pay for information or products on Air Quality.

Overview of Copernicus programme benefits

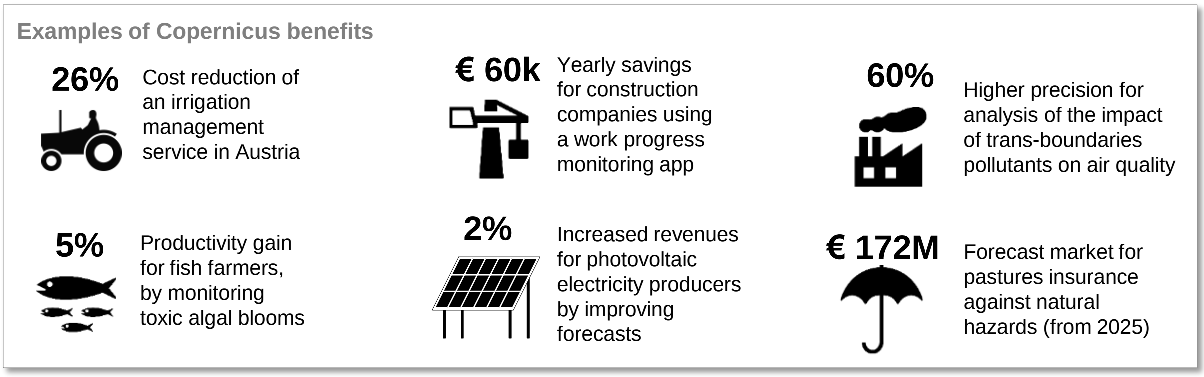
The following figure sums up the key impacts of the overall Copernicus programme, including both the economic value generated and the supported employment. The impacts are quantified across both the upstream segment and in the EO downstream and end user markets. It should be noted that the EO downstream and end users benefits were only assessed in the 8 value chains presented above: Agriculture, Forestry, Urban Monitoring, Insurance, Ocean Monitoring, Oil & Gas, Renewable Energies and Air Quality.



It should be noted that the employment figures represent the cumulative person years over 2015-2020 rather than the number of jobs sustained at any one time..

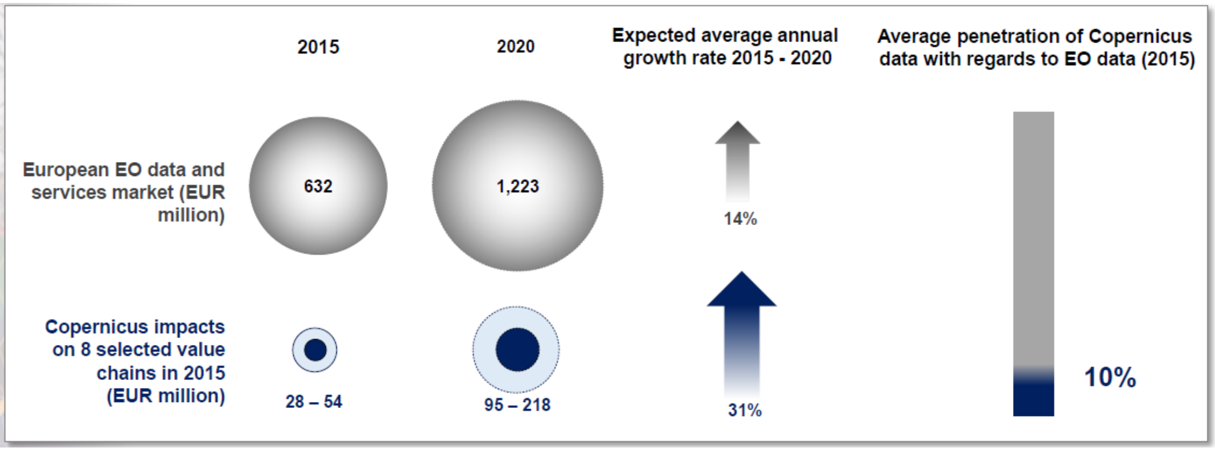
Examples of Copernicus benefits across selected value chains

The following figure provides some examples of the contribution of Copernicus to various projects and initiatives across the selected value chains. More details can be found in the case studies presented for each sector in this report.



Overview of intermediate users' benefits

Intermediate users constitute the main link between the space infrastructure of Copernicus and the wider community of potential users of Copernicus-enabled products and services. Also referred to as the EO and GIS downstream markets, they are typically Value Added Services (VAS) companies and other EO experts, processing raw data to turn it into useful information for end users. These actors are mainly oriented towards commercial markets, and today the main reasons for low benefits from Copernicus in some value chains are the low willingness to pay of end users (e.g. for Air Quality products), the gap between end users' specific needs for tailored products and the available solutions (e.g. Insurance), or the still recent adoption of EO-based products in general on the market (e.g. Renewable energies).



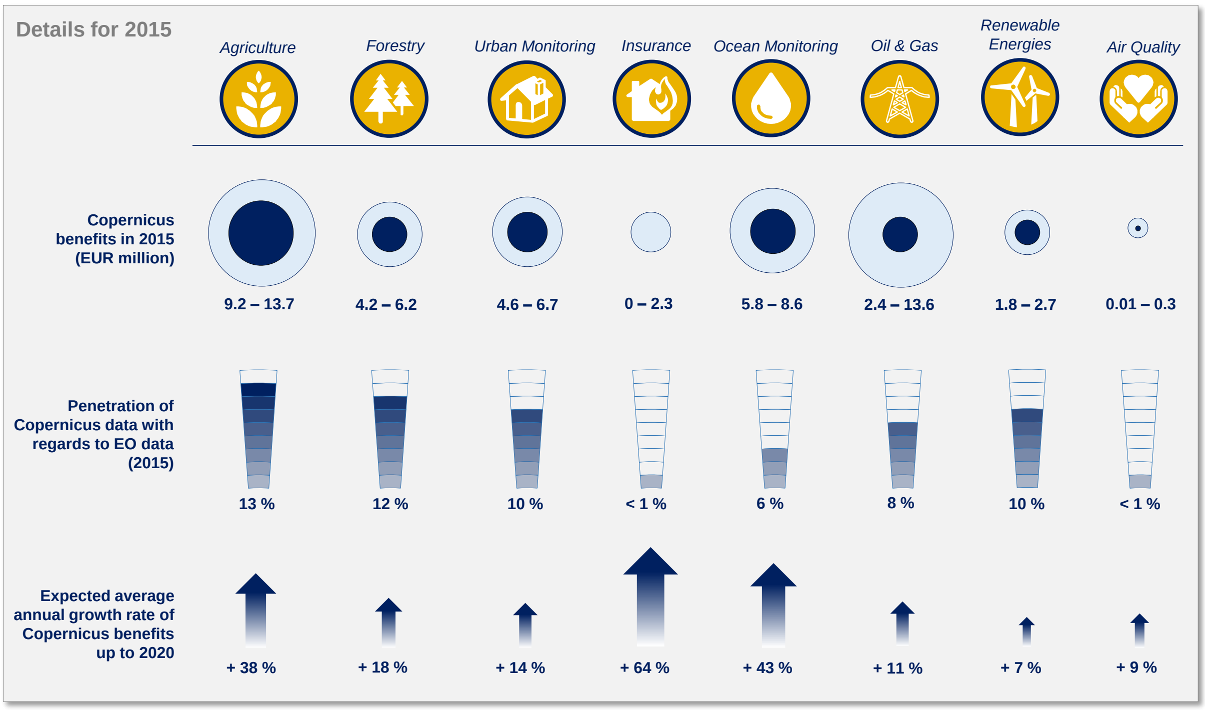
66 % Proportion of intermediate users (companies) exploiting **Copernicus data** in Europe

27 % Proportion of intermediate users (companies) exploiting **Copernicus services** in Europe

2.75 million # products downloaded on the **Scientific Hub** (November 2015)

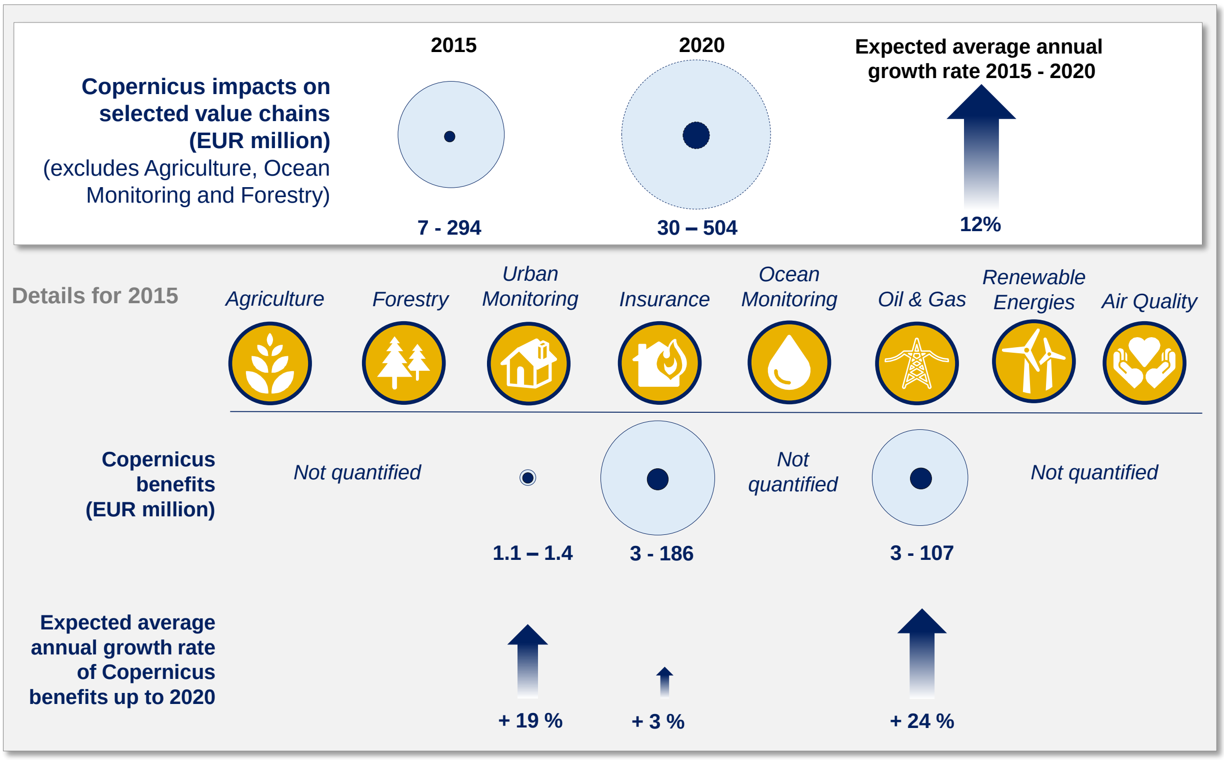
240,000 # products downloaded on the **Collaborative Hub** (November 2015)

The benefits of Copernicus vary across the value chains, depending on the weight of the domain in the EO downstream market and the penetration of Copernicus. Though some value chains are expected to see very high growths in coming years (particularly Agriculture, Insurance and Ocean Monitoring), all the sectors considered are forecast to witness an increase in Copernicus economic impacts.



Overview of end users' benefits

End users represent potentially much larger markets than the EO / GIS downstream markets, and so offer the prospect of potentially substantial benefits from Copernicus, for instance for Oil & Gas companies, (re)insurers or agricultural cooperatives. They generally have very specific needs, but demonstrate high willingness to pay to access tailored EO-based products with real added value for their business.



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Abstract

Following the assessment of the Copernicus programme's impacts on the upstream segment, this study aims at characterising the benefits of and the barriers to the Earth Observation (EO) downstream and end user markets in Europe, in order to identify the levers that can support the development of economic activity exploiting Copernicus.

After a review of the existing literature, the EO downstream market is characterised by using the US Landsat programme as a benchmark, by the role of large ICT players, the flourishing of platforms and cloud computing, and the overall Big Data trend.

The European market is then investigated in detail for 8 promising value chains through consultation with a wide panel of stakeholders, to characterise the current impact of Copernicus according to economic, social, environmental and strategic perspectives, and to forecast the evolution of its contribution to growth and employment up to 2020. Based on the identified strengths, weaknesses, opportunities and threats, recommendations are provided globally and specifically for each value chain, to foster market uptake by European companies. Though still rather low, the penetration of Copernicus data in the EO market is expected to grow in the future, with substantial benefits for both intermediate and end users.

Taxonomy and definitions

In the assessment of socio-economic impacts and the characterisation of the Earth observation market, different taxonomies may be adopted which may influence the interpretation of the results. It is therefore important to provide a clear classification and an unambiguous description for the types of impacts assessed. This section also presents a list of definitions for the most widely used macro-economic, industrial, or subject matter (space) terminology used within this report. The taxonomy and the most important definitions are set out in the table below.

Socio-economic impacts taxonomy

Item	Description
Cost Benefit Analysis (CBA)	A CBA is a methodological economic approach aiming at comparing all the costs and benefits derived from a given investment. More details are available in the Socio-economic assessment section.
(GDP) Direct impact	Economic activity in the space industry supported by the injection of spending
Earth Observation (EO)	Earth Observation (EO) can be carried out by satellites or airborne (aircraft, drones etc.). EO refers in this study to the activity using satellites to monitor Earth from Space. Remote sensing is used in this study as a synonym for EO.
Employment impact	Impact on employment associated with increased economic activity
Employment multiplier	Ratio between the total employment supported by direct, indirect, and induced economic activity and the direct employment
Enabled revenues	Sales (other than those financed by the EC) by European producers that would not have been achieved if the space programme under examination had not occurred.
European space industry enabled revenues	Enabled sales of space-related industries (e.g. satellite hardware and services)
GDP impact (or Economic impact)	The impact of injection of spending on regional, and national economies as measured by gross domestic product (GDP)
Gross Value Added (GVA)	Measures the GDP impact (Space Gross Value Added represents the Direct GDP impact, while Additional Value Added represents the sum of the indirect and induced GDP impact). Total GVA (equal to the sum of space GVA and additional GVA) represents the total GDP impact
(GDP) Indirect impact	Economic activity supported by the expenditures of suppliers of goods and services to support the space industry orders
(GDP) Induced impact	Economic activity supported by those directly or indirectly employed in the space industry (i.e. employed in space suppliers) spending their incomes on goods and services in the wider European economy
Non-space industry revenues	Enabled sales of non-space related industries
Other quantitative impacts	Other quantifiable socio-economic impacts of investments in the space programme
Patents	Number of patents developed in the programme
Publications	Number of scientific paper produced within the programme
Qualitative impacts	Non-quantifiable socio-economic impacts of the space programme (technical advancements, positive business externalities, outreach impacts, etc.)
Sales multiplier	A ratio that relates the size (revenues) of the enabled economy to the size of the upstream injection of funds by EC

Type II GDP Multiplier	Type II GDP multiplier captures both indirect and induced effects. $Type\ II\ GDP\ Multiplier = \frac{(Direct\ Impact + Indirect\ Impact + Induced\ Impact)}{Initial\ Spending}$

Earth Observation taxonomy and definitions

Concept	Definition
Active remote sensing	NASA defines active sensing instruments as instruments that "provide their own energy (electromagnetic radiation) to illuminate the object or scene they observe. They send a pulse of energy from the sensor to the object and then receive the radiation that is reflected or backscattered from that object." Radar or laser altimeter are examples of active sensors. This type of technology enables day and night monitoring during all-weather conditions but it leads to a higher consumption of battery power.
Agricultural system	An assemblage of components which are united by some form of interaction and interdependence and which operate within a prescribed boundary to achieve a specified agricultural objective on behalf of the beneficiaries of the system.
Air pollution	The introduction by humans, directly or indirectly, of substances or energy into the air resulting in deleterious effects of such a nature as to endanger human health, harm living resources and ecosystems and material property and impair or interfere with amenities and other legitimate uses of the environment.
Biomass	Biomass is material of biological origin which derives from living or recently living organisms. It is used to produce energy directly by combustion, indirectly through biogas produced by methanisation or through biofuel produced by chemical transformation.
Canopy	A roof made of the intertwined branches, twigs and leaves of the forest's taller trees
Claim-based insurance	The insurer pays an indemnity after receiving a claim of loss from its customer.
Contributing mission data	Contributing mission data means space-borne Earth observation data from contributing missions licensed or provided for use in Copernicus
Contributing missions	Contributing missions means space-based Earth observation missions providing data to Copernicus complementing data provided by the dedicated missions.
Copernicus data	Copernicus data means dedicated mission data, contributing mission data and in situ data
Copernicus services	The Copernicus entrusted entities are delivering free products and services based on Copernicus data to manage and protect the environment and natural resources, and ensure civil security. Copernicus services will provide essential information for six main domains: ocean, land and atmosphere monitoring, emergency response, security and climate change.
Copernicus users	Copernicus users means: • Copernicus core users: Union institutions and bodies, European, national, regional or local authorities entrusted with the definition, implementation, enforcement or monitoring of a public service or policy in the areas referred to in point (a) of Article 2(2); • Research users: universities or any other research and education organisations; • Commercial and private users; • Charities, non-governmental organisations and international organisations.
Covariate risk	Case where a cause affects neighbouring individuals at the same time. This is especially the case for natural disaster insurance.
Dedicated mission data	Dedicated mission data means space-borne Earth observation data from dedicated missions for use in Copernicus
Dedicated missions	Dedicated missions means the space-based Earth observation missions for use and operated in Copernicus, in particular the Sentinel missions
Downstream sector	The downstream sector includes all actors involved in exploiting the EO space data and providing EO-related products and services to end users. This includes in particular Value Added Services (VAS) and geo-information companies, whose core business is to

	process satellite EO data and turn it into geo-information products, usable by the final users. The data is aligned against reference frames (in time and space), and becomes comparable with other data generated by other EO instruments. It is important to note that the EO downstream sector does not include specific consumer equipment manufacturing (e.g. GNSS receivers for Navigation or satellite dishes for Telecommunications).
Earth Observation domain	EO domain encompasses satellites for meteorology as well as for remote sensing of planet Earth.
Emergent layer (related to forest)	Consists of the tallest trees which stick out above the canopy
End user	End users include both institutional actors (e.g. meteo agencies, emergency services, forestry offices, scientific laboratories…) and private ones, which use services delivered by intermediate users to asses various applications.
Entrusted entities	Entrusted entities are institutional or private stakeholders which receive procurement from the European Commission to develop, establish and operate a service and an observation capacity meeting the demands of users.
Food security	Food security can be defined as including both physical and economic access to food that meets people's dietary needs as well as their food preferences. It is based on three pillars: food availability, food access and food use.
Forest	A forest matches three characteristics: land area (minimum 0.5 hectares), tree height (minimum 5 metres), crown cover (at least 10 percent).
Forest floor	Mostly covered with decaying leaves, twigs, fallen trees, animal waste, moss and other organic materials
Geographic Information System	An information system which allows the user to analyse, display, and manipulate spatial data, such as from surveying and remote sensing, typically in the production of maps.
Hydroelectric energy	Hydroelectric energy is produced exploiting hydropower, which is the power generated through the gravitational force of falling or flowing water.
Hydroelectric energy	Hydroelectric energy is the term referring to electricity generated by hydropower; the production of electrical power through the use of the gravitational force of falling or flowing water.
Idiosyncratic risk	A situation where an individual exposure is not related to its neighbour's exposure.
In situ data	*In situ* data means observation data from ground-, sea- or air-borne sensors as well as reference and ancillary data licensed or provided for use in Copernicus
***In situ* sensor**	In-situ sensors provide various data about their local environment, by measuring physical and chemical parameters at a given spatial position. It can designate for instance sonars, thermometers, wind gauges or ocean buoys
Index insurance (or parametric)	Customers are compensated based on the computation of an index related to the insured losses, which is compared to a threshold to define the level of indemnity.
Insurance	Relies on the concept of "risk transfer", where an insurer transfers a risk from its client in return of an insurance premium.
Intermediate user	EO intermediate users include institutional and private users using EO data as a raw material. These users build value added services based on EO data among others sources for specific applications before selling them to end users.
Irradiance forecast	Irradiance forecast is the forecast of direct irradiance with a horizon of up to 48 h.
Land	A delineable area of the Earth's terrestrial surface, encompassing all attributes of the biosphere immediately above or below this surface including those of the near-surface climate the soil and terrain forms, the surface hydrology (including shallow lakes, rivers, marshes, and swamps), the near-surface sedimentary layers and associated groundwater reserve, the plant and animal populations, the human settlement pattern and physical results of past and present human activity (terracing, water storage or drainage structures, roads, buildings, etc.) .
Land applications	According to the EARSC taxonomy, land applications cover all types of applications which are focused on natural land areas even if they involve human intervention.
Land use	The arrangements, activities and inputs people undertake in a certain land cover type to produce, change or maintain it.
Marine and Ocean	All maritime-focused applications whether natural or human-oriented

Mesoscale modelling	Mesoscale modelling is used in meteorology and oceanography for modelling a horizontal atmospheric layer that has a diameter bigger than 2 km and smaller than 2000 km. It is an intermediary scale between the synoptic scale (ocean streams, anticyclones, etc.) and the microscales that have diameter smaller than 2 km.
Midstream sector	The midstream sector includes actors involved in operating EO satellites, receiving and handling raw data and storing it for further processing and/or user access: • EO satellite operators • EO data service providers • EO ground support infrastructure and equipment suppliers
Numerical model	A representation of an environment through a set of equations that can only be solved by a computer
Ocean economy	The economic activities that directly or indirectly take place in the ocean, use outputs from the ocean, and put the goods and services into the ocean's activities
Offshore activities	Offshore activities refer to O&G maritime activities.
Onshore activities	Onshore activities refer to O&G activities performed on land.
Passive remote sensing	According to the definition of the Earth Observatory of NASA, passive instruments "detect natural energy that is reflected or emitted from Earth. [...] Reflected sunlight is the most common external source of radiation sensed by passive instruments." EO satellites use a variety of passive remote sensors, such as radiometers or spectrometers.
Platform	A platform is an IT interface with an Application Programming Interface (API) based on a software to enable the different users to handle EO data/services more easily.
Precision farming	Managing crop production inputs (seed, fertilizer, lime, pesticides, etc.) on a site-specific basis to increase profits, reduce waste and maintain environmental quality.
Prime insurance	Transfers risks from a client which can be individuals, companies or organisations towards the insurer. The contract specifies a value insured in case of an event, and the insurance premium received by the insurer for handling this risk.
Radiometric resolution	Radiometric resolution: the radiometric resolution (expressed in bit per second) describes the variability in a single pixel. It basically means how much information is present in a pixel, ranging from a binary black and white pixel to the high radiometric resolution with colours and shadows. A higher radiometric resolution does not necessarily means a better imagery quality, it always depends on what information the end user wants to extract;
Radiometric resolution	Radiometric resolution refers to the sensitivity to the magnitude of electromagnetic energy, or also how much information is in a pixel (expressed in units of bits). Another way to express it is how well the differences in brightness in an image can be perceived. As for the spatial resolution, digital camera companies weigh the trade-off between quality of the image and how many pictures can be stored on a camera.
Reinsurance	Transfers risks from an insurer towards the reinsurer. The contract specifies a value insured in case of an event, and the insurance premium received by the reinsurer for handling this risk.
Remote sensing	The scanning of the earth by satellite or high-flying aircraft in order to obtain information about it.
Renewable energies	Renewable energies encompass non-fossil sources: wind, solar, aerothermal, geothermal, hydrothermal, ocean energy, hydropower, biomass, landfill gas, sewage treatment plant gas and biogases
Solar energy	Solar energy is radiant light and heat from the Sun that is harnessed using a range of ever-evolving technologies such as solar heating, photovoltaic, solar thermal energy, solar architecture and artificial photosynthesis. Solar energy is mainly produced through solar photovoltaic (PV) or solar thermal energy.
Spatial resolution	The spatial resolution is based on the size of a pixel on an EO image (meter per pixel). Low, medium, high and very-high imagery resolution can usually be available to VAS. Depending on the exact need of the end user, a broad picture of low resolution can be sufficient, but in some cases the user requires a specific area to be monitored with very-high resolution;

Spectral resolution	The spectral resolution represents the wavelength used to produce the EO imagery. Different types of wavelength band of a given sensor (radar for example) can usually be offered by the same satellite. The wavelength band choice is tied to what needs to be detected: each band is more suitable than another to monitor a specific element. For example, some wavelength are appropriate to monitor the upper part of trees, with others it is possible to see through trees to map soils or underground materials
Sustainable agriculture	The efficient production of safe, high quality agricultural products, in a way that protects and improves the natural environment, the social and economic conditions.
Temporal resolution	The temporal resolution refers to the revisit time or period which represents the period of time necessary for a satellite to complete an entire orbit cycle. One entire orbit circle refers to the time necessary for a satellite to take a second picture of the exact same area at the same viewing angle. Satellite orbit and altitude play also a significant role since some areas on Earth are re-imaged more frequently depending on orbit/altitude. Collecting and comparing multi-temporal imagery of the same area enable to detect changes and extract interesting information for the end users.
Third party data and information	Third party data and information means data and information created outside the scope of Copernicus and necessary for the implementation of its objectives;
Tree	A woody perennial with a single main stem, or, in the case of coppice, with several stems, having a more or less definite crown; includes bamboos, palms and other woody plants meeting the above criteria
Understorey	Made up of bushes, shrubs and young trees
Upstream sector	The upstream sector includes all actors involved in the value chain leading to an operational EO space system: • EO satellites and ground segments manufacturers • Launch services providers (activity related to EO only) • EO payloads manufacturers (optical and radar instruments) • Space agencies EO programmes
Urban area	Characterised by a build-up environment, consisting of non-vegetative, human-constructed elements (e.g. roads, buildings, runways, and industrial facilities
Urban management	A set of instruments, activities, tasks and functions that assures that city can function
Value Adding	This covers the activity of processing satellite data probably combined with other data to generate EO products or application products sometimes referred to also as thematic products.
Wind energy	Wind energy (or wind power) describes the process by which wind is used to generate electricity, which can be produced by on-shore or off-shore wind turbines.

Executive summary

Introduction

Earth Observation (EO) comprises the use of remote sensing technologies to monitor the land, sea and atmosphere. In this context, the European Union is currently developing an independent EO capacity through its Copernicus programme. This consists of a set of components that collect data from various sources: EO satellites (the Sentinels) and a multitude of in situ sensors (meaning on site or local) on the ground, at sea, or in the air. Copernicus responds to the needs of its users – European citizens – in their daily lives through its six thematic services (Land, Marine, Atmosphere, Climate, Emergency and Security) by supporting the development of many applications, thus contributing to the "excellence of European industry in space".

This document has been prepared as the outcome of the assignment "Study to examine the socio-economic impacts of Copernicus in the EU". Its purpose is to provide a detailed review of the impact of the Copernicus programme on the EO downstream market, with a focus on ten downstream domains/user segments ensembles – referred to here as 'value chains'. The selected value chains are: Agriculture, Forestry, Urban monitoring, Insurance with a particular focus on natural hazards, Ocean monitoring, Oil & Gas, Renewables energies, and Air quality management, as well as two benchmark value chains which are Landsat and EO 2.0 actors.

A two-fold approach has been followed in the study. Firstly, extensive desk research was carried out to analyse the different methodologies used to assess economic and societal impacts, the characterisation of the EO downstream market characterisation and the sectoral use of EO data. The second phase of the study was based on a stakeholders' consultation during which 142 experts from 94 entities were interviewed.

Part (a) – Theoretical predictions and review of literature

Methodology

The objective of the literature review was to identify the most suitable methodologies for the assessment of the Copernicus downstream industry. It highlighted the main difficulty in assessing the benefits derived from the use of EO data, namely the extent to which the benefits could be directly attributed to or associated with Copernicus data. The methodology that was adopted needed to capture the diversity and complexity of the effects that follow from the use of EO data, in terms of both economic and societal benefits. For this reason the BETA methodology was selected, providing a robust and accurate micro-economic approach to assess the attribution of economic benefits.

The BETA methodology was originally developed in order to better understand the economic benefits made possible by public investment in space activities, and was subsequently applied in other frameworks. The methodology relies on face-to-face interviews with executives from a large number of firms that have received contracts from a national space agency. The rationale behind this approach is to understand and capture the value-added of the expertise developed by the company having work under a contract for a space agency. The methodology is commonly accepted by both economists and space agencies for the measurement of spin-off impacts derived from public investment in space activities. The quantification method is based on the information gathered during direct interviews and on secondary data such as internal documents from the companies, studies from expert groups, etc.

Two types of impacts are assessed throughout the study:

1. **Enabled revenues**, which are estimated throughout a microeconomic approach. Three types of effects have to be assessed in order to understand the impacts of Copernicus on private end users:
   - **Market effect**: the availability of open and affordable Copernicus data enables an innovative offer for private end users, increasing sales of existing and new products and creating a new department/company in a new market
   - **Commercial effect**: the availability of open and affordable Copernicus data enables the development of a new or/and better commercial network for private end users
   - **Organisational effect**: the availability of open and affordable Copernicus data enables organisational improvements within the organisation

2. **Societal and wider impacts**, which include all impacts that are quantifiable but not monetary in nature and include social benefits such as increased safety and society, national prestige, environmental impacts, outreach impacts, etc.

Part (b) – Earth Observation downstream market characterisation

The traditional EO downstream value chain

The EO downstream market represents all the economic and societal impacts enabled by the information extracted from the data provided by EO satellites. The data is processed by intermediate users providing Value-Added Services (VAS), in partnership with specific satellite operators, which then distribute it to the end users which are of two types: institutional (such as ministries, governmental agencies, etc.) and commercial (companies).

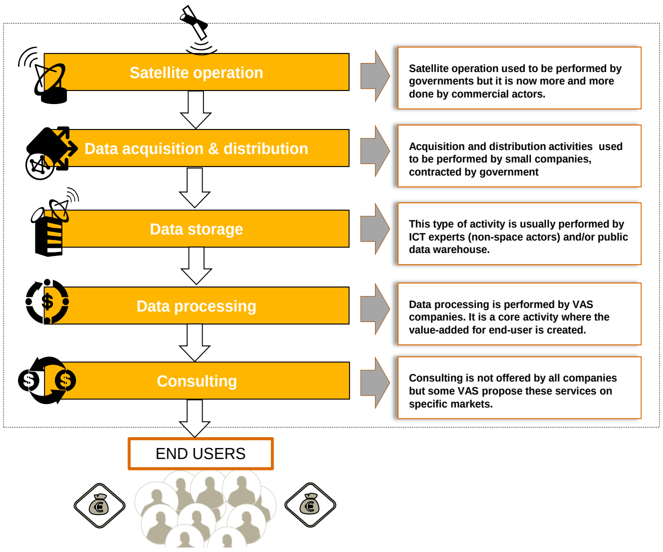


Figure 1 - EO downstream value chain principal activities (Source: PwC-Strategy& analysis)

The EO downstream market is made up of a 5-step linear multi-stage process which is summarized in the adjacent figure: Satellite operation, Data acquisition & distribution, Data storage, Data processing, and Consulting.

The **digital image processing step** can be decomposed in four main activities:

- **Pre-processing**: in order to improve image quality for later analysis by removing the undesirable influence of atmospheric interference, system noise and sensor motion
- **Display**: which corresponds to image enhancement (the ability to enhance the view of an area by manipulating pixel values) and image transformation (in order to compare heterogeneous multi-temporal EO data thanks to the different wavelength available)
- **Analysis**: which comprises on digital image classification, combining several images with different characteristics in order to create a global image with useful information
- **Output**: during which remote sensing is used to detect changes over time and/or providing the information product

The EO downstream market in figures

The EO data and VAS have already made up a steadily growing market over the past decade, but the sales are expected to expand rapidly in the coming decade. Indeed, **the revenues of the market for imagery, including both data sales and value-added services, have grown significantly in recent years from EUR 2,738 million in 2015 to EUR 3,092 million in 2016 representing growth of 12.8%**. One actor currently dominates the market, namely the US-based firm **Digital Globe, accounting for 63% of the EO global market**. The sales of EO products mostly target **Defence & Intelligence** with **36% of overall sales worldwide in 2015**. In terms of geographic distribution, **North America is the main market for the EO downstream sector,** followed by Europe & Middle-East Africa and Asia-Pacific.

By 2020, the market is expected to reach EUR 5,282 million. In terms of geographic distribution, Europe & Middle-East Africa and Asia Pacific are expected to grow significantly, accounting respectively for 28.7% and 23.8% of the overall market. North America is however expected to stay the largest market worldwide. **Cloud platform holders are expected to play a major role** in the EO data market in the coming decade by making available very high resolution (VHR) data, which is responsible for the largest growth in EO data. In addition, the increased data supply is bound to put pressure on the pricing of medium and high resolution data with low/medium resolution data already being widely available (in particularly in the context of the Landsat and Copernicus programmes).

The **European EO downstream market** is estimated to represent 22.5% of the worldwide market of EUR 2,738 million (2015), or **approximately EUR 615 million**. The split of the European downstream activities is as follows: the largest share is taken up by VAS companies, followed by satellite operations/data sales activities and hardware/software providers. **VHR data is the main source of EO data sales, with 44.7% of European EO data sales**, accounting for almost 50% of the sector revenues.

Competitive Dynamics on the EO downstream market

The EO downstream market is experiencing increasing competition with the emergence of new private actors (such as EO 2.0 and space start-ups in the imagery market, primarily upstream actors who have recently developed downstream services) and new governmental actors (such as emerging countries investing in the development of their own EO activities). In this context, EO satellite manufacturers have pursued **vertical integration strategies** to capture new revenue streams, such as the acquisition of specialised companies.

One potential threat to satellite-based imagery could be the Unmanned Aircraft System (UAS) which provides very useful high resolution imagery to calibrate very specific areas. They can be used as a substitute for VHR data but are complementary to medium and high resolution data, such as that delivered by the Copernicus programme. The UAS market is expected to grow rapidly in the future if it overcomes three main barriers: national regulatory frameworks to facilitate the use of commercial UAS, insurance related to the use of drones (which needs to be developed for liability reasons), and privacy, meaning that specific air traffic control is required to ensure that drones so not violate restricted airspace.

A global **Geographic Information System (GIS)** can be defined as a “computer information system that can input, store, manipulate, analyse, and display geographically referenced (spatial) data to support decision making processes". A GIS product comprises not only imagery data but also many different types of data (in-situ, social media, commercial and public data) which are aggregated through the application of powerful computing and analytics power in order to create dynamic links between imagery and very specific information to respond to very specific end-user requirements and create a very high value-added unique output. T**he GIS market is much larger than the EO downstream market** with an estimated value of EUR 6,814 million in 2014, and can be considered as a growth opportunity for the EO downstream market. By combining different types of data (satellite-based EO data, airborne data, in-situ data, social media, etc.), very high value added products are developed for the end users, leading to the development of a large market. Many EO downstream actors are attracted by this market since companies in the EO downstream sector have a competitive advantage in processing imagery and providing value added products and services. Hence, the strong growth of the GIS market should be seen as an opportunity for growth for EO downstream actors.

The GIS market and new trends related to ICT

The EO downstream market is more and more dependent on GIS**.** The GIS market has several synonyms such as Geo-spatial market, but they all refer to the same content. **GIS enables users to create dynamic relations between spatial geo-referenced data and situational/relational data based on the specific needs of users such as internal statistics or in-situ data.** Satellite-based EO data and airborne data (including UASs data) are at the heart of GIS products and services. GIS providers supplement this core imagery with many other sources of data (in-situ data, navigation data, social media information etc.) and users can also upload their own data directly to GIS platforms.

The overall GIS market is much larger than the EO market and is estimated to be around EUR 8,754 Billion in 2015. With a forecast CAGR of 10.4% over 2015-2020, the GIS market is projected to reach EUR 14.29 billion by 2020. Three "sub markets" can be identified within the GIS market: the GIS software market worldwide, the GIS data market worldwide and the GIS services market worldwide. Geographically speaking, the current GIS market for Europe, Middle-East and Africa (EMEA) is valued at EUR 2,881 billion and is expected to reach EUR 4,038 billion by 2020, with an average CAGR of 9.3% over 2015-2020. No data to distinguish Europe from Middle East and Africa was found, but Europe is expected to be by far the main contributor to the GIS market for EMEA.

The Copernicus programme reflects the current context where boundaries between the EO downstream, GIS and downstream markets are blurring. The problems to be solved by society are more and more complex, such as climate change or water management. EO plays a role in most of the main challenges faced in the 21st century, but this source of data is only one part of the solution; imagery has to be integrated with a vast variety of other data to respond to such complex problems. The Copernicus programme is the largest in size and scope to have tried to connect the traditional EO downstream market with the wider GIS ecosystem. Responding to today's context of the digital economy and Big Data paradigm, the Copernicus programme is an EO programme offering much more than other forms of EO data. Indeed, throughout its three main components (space, in-situ and services components), the Copernicus programme is unique, bridging many user communities both from the public and the private sectors.

Part (c) – Data access and dissemination

Data access and data dissemination in the EO downstream market

Data access and dissemination is essential for any EO mission. The value of a free and open data programme depends on the scale of the use of the data. EO missions have an initial operational phase in which the data produced by the on-board instruments are validated on the ground once acquired. Then, the data are made available to users in two ways:

- **Near real-time data access**, meaning that the data are generated on board, received on the ground, processed and immediately made available
- **Long-term data access**, during which the data are made available in the form of access to the mission archive database

The data exploitation chain comprises several interconnected stages described below.

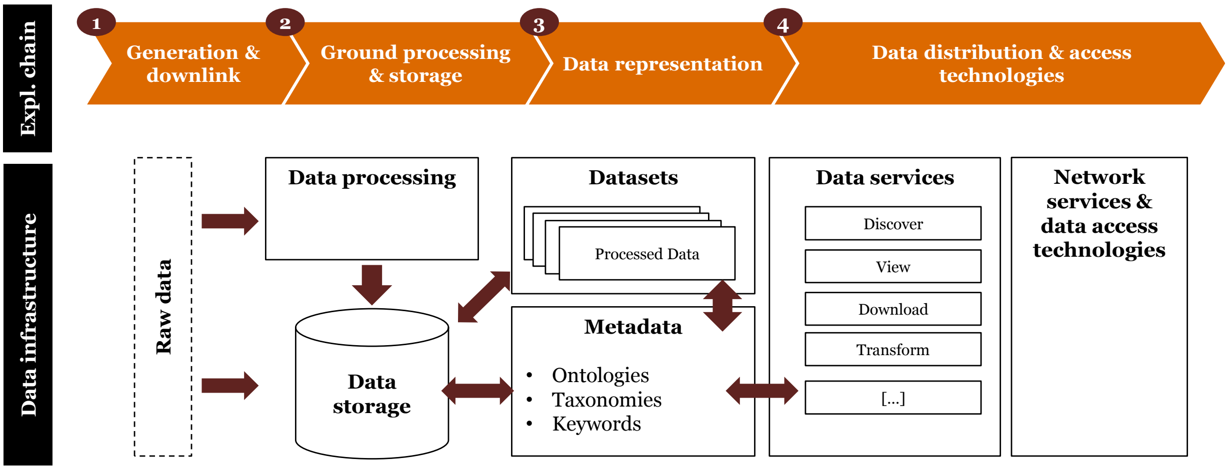


Figure 2: Data exploitation chain (Source: PwC-Strategy&, 2015)

1. **Generation and downlink**: EO satellites continuously monitor Earth surface and produce data which is then downlinked to ground stations.
2. **Ground processing & storage**: which corresponds to an automatic re-integration of the data.
3. **Data representation**: data are organised into meaningful sets throughout calibration, geo and time referencing and annotated specific information. Datasets are then transformed into metadata which provide specific definitions or keywords to be easily identified. The long-term preservation of data access for this type of files in EO programmes poses important issues in terms of storage capability and costs since several programmes such as Copernicus produce a very large amount of data every year.
4. **Data distribution and access technologies**: which provide end users with different data services (discovering, visualising, downloading and transforming).

Several new trends related to Big Data and cloud computing are disrupting the way users discover, visualise and transform EO data in the EO downstream market. The first one relates to **Big Data trends**, whose five key characteristics (the 5Vs, meaning Volume, Variety, Velocity, Value and Veracity of Data), each present their own issues. Indeed, the information layers require powerful computing and analytics power to capitalize on the multiple sources of data. This is particularly challenging because the current structure of the Copernicus infrastructure does not enable such automatic processing and does not facilitate access to Copernicus data and products because the downloading rate offered is not sufficiently fast.

The second emerging trend which could have an impact on the dissemination of EO data is **cloud computing**, which refers to the delivery over the internet of hosted services enabling users to share computing resources without the need to build and maintain dedicated computing infrastructure in-house. Cloud computing offers several advantages: it is a new way to access data that facilitates storage in a context of increasing volume of data and eases the access of technical types of data by non-technical actors. **The cloud computing services market amounts to EUR 19.65 billion worldwide in 2016 with a projected CAGR of 21% for 2015-2020**. There is strong competition between cloud providers such as Amazon Web Services (AWS), Google, Microsoft, Oracle or IBM. This impressive market growth combined with strong competition is stimulating demand for new platform features and new sources of data, in particular in the context of open EO programmes such as Copernicus. Several cloud providers have already developed some initiatives to provide EO open data on their platform. Cloud-based platforms provide end users with access to large-scale processing power with all the data required, updated regularly with new data, replacing the need to invest in their own computing power or storage capacity. In parallel, it allows EO service providers to have access to larger streams of revenues.

The Landsat programme

The Landsat programme is a joint collaboration between NASA and the US Geological Survey (USGS) which was initiated more than 40 years ago, where NASA has responsibility for procurement (satellite infrastructure and launch) and USGS for operation and exploitation. **In 2008, the USGS decided to implement an open data policy through a web-based platform**. Since then, downloads have been increasing every year, reaching **almost 1 million scenes downloaded per month in 2015**, far more than the figures that are currently available for Copernicus. Indeed, up to November, 30, 2015, more than 2,750,000 products were downloaded on the Scientific Hub and around 240,000 on the Collaborative Hub. These figures are encouraging since the Copernicus access infrastructure only opened in 2014, but is still very small compared to the Landsat programme.

Since May 2015, the **Amazon Web Service (AMS) launched public hosting of Landsat-8 imagery on an online platform**. AWS has positioned itself as an intermediate that fosters Landsat data utilization and supports market growth. Hence, USGS does not regard large companies that use Landsat data such as AWS, Google or Microsoft are a threat but rather an opportunity, allowing them to focus on improving its response to user communities. Today, the Landsat programme has the longest-duration archives in the world for medium spatial resolution land remote sensing data.

The role of USGS and the type of products offered by the agency brings interesting perspectives for the Copernicus programme, especially related to the questions of public/private boundary, Landsat data access and data dissemination policies. USGS has decided over time to provide an increasing number of high-level products in a standardized way which are not provided by any US commercial EO downstream actor. The Landsat experience shows how a large public investment led to the creation of a national capability. Indeed, the Landsat programme ranks 2nd, just after GPS, in terms of strategic importance for the US and is considered a national capability. Over the four decades, a large ecosystem of users has been developed around a large pool of governmental and scientific users, developing Business-to-Business (B2B) relationships. The essential step in creating the whole ecosystem was the development of a local/internal scientific market for Landsat data in the US.

Regarding the socio economic value of the Landsat imagery, the willingness to pay of the users seems to be quite high. However, USGS does not carry out any economic assessment of the economic value of Landsat applications. Several case studies were produced by the “Social and Economic Analysis Branch” of the USGS, but these do not include quantitative figures but rather assess the way and extent to which Landsat data is used in various fields such as agriculture, forestry, disaster monitoring, etc.

The Copernicus programme

The Copernicus data access and distribution infrastructure is based on European Space Agency (ESA) EO missions implemented over the last 20 years. The network of data repositories is distributed all over Europe and shared with national space agencies and several commercial missions. The Copernicus programme was developed using Processing and Archiving Centres, ESA’s specific ground segment with fast delivery capability offering EO data less than three hours after acquisition. In comparison with the Landsat programme, **the Copernicus programme only offers one regular channel to access and download Sentinel raw data or products on a one-by-one scene basis**.

In order to foster the dissemination of Copernicus data, data access should be harmonized, on top of the existing distribution and dissemination data infrastructure to foster the dissemination of Copernicus data. The implementation of ESA Thematic Exploitation Platforms is another way forward for the Copernicus programme since they try to make as much use as possible of open source software, tools and applications free-of-charge. However, particular attention should be paid to avoid any overlap between platforms to avoid redundancy and duplication of sources of information. In addition, a substantial effort is required to promote the usefulness of these platforms to a large user community.

EO 2.0 companies

EO 2.0 companies illustrate well the new trends and tendency and help to better highlight and understand the novel business models and potential new markets enabled by the emergence of these private ventures. EO 2.0 is a term that encompasses New Space industry players operating in the EO business. **EO 2.0 players include new start-ups in North America entering the imagery market with a vertically-integrated structure** (from satellite-manufacturing to products and services provision) such as Terra Bella (formerly Skybox Imaging), Planet Labs, Spire Global and Urthecast. Nano/micro-satellites are much quicker to build, and much cheaper to deploy, which implies shorter reaction times and greater flexibility. Hence, EO 2.0 companies are subject to a much lower financial risk associated with asset loss. The core differentiating factor of these companies compared to EO incumbents is their capacity to monitor in real-time a given geographic area at a given time. This capacity will potentially enable a near-real time monitoring with medium, high and very high spatial resolution at low cost, which may stimulate demand and create a new market of products.

EO 2.0 companies have a very high capacity to attract investment, more than all other entities in the EO downstream market. From 2000 to 2015, more than EUR 11,884 million was invested in start-up space ventures. This capacity attracts the interest of the business press, contributing to a marketing effect for such companies. This new phenomenon has also raised awareness among the general investment community and, to a certain extent, the general public.

New Space imagery companies rely on strong cloud expertise and computing power, together with high software development capacity. These three factors together give EO 2.0 companies a competitive advantage compared to more conventional EO downstream companies but also offer the opportunity to easily move into the very attractive GIS market, especially the cloud GIS market. This market has already set up a digital environment through the development of powerful analytics platforms.

The growth strategies of EO 2.0 companies are subject to various influences. **EO 2.0 endeavours are generally kick-started by private investment, especially from venture capitalists (VCs)**, and so there is strong pressure to deliver value. EO 2.0 companies' growth strategies are intrinsically linked to the goals of VCs to increase the value of these ventures and attract additional investors. The focus is for VCs to have potential exit opportunities. Two different approaches were used by EO 2.0 companies: acquired traditional EO downstream actors or being acquired by large companies. These strategies underline the strong power of investors over EO 2.0 actors.

Companies in the traditional EO downstream market are currently adopting an attitude of "wait and see". Digital Globe, for example, does not perceive EO 2.0 companies as a threat, noting that start-ups attracted VCs without demonstrating clear prospective revenue streams. They envisage developing partnerships with such companies in the near future. However, Digital Globe's plan for a new joint venture with the government of Saudi Arabia can be interpreted as a reaction to new competitors. In contrast, Airbus DS considers EO 2.0 actors and New Space companies as real threats.

Part (d) – Analysis of Copernicus opportunities in sectoral value chains

The benefits of Copernicus for EO downstream businesses and end uses markets were assessed for 8 selected value chains: Agriculture, Forestry, Urban Monitoring, Insurance, Ocean Monitoring, Oil & gas, Renewable Energies and Air Quality. Over the 2015-2020 period, the cumulative revenues that could be enabled by Copernicus are estimated at **between EUR 480 million and EUR 3,135 million for the EO downstream and end user markets**. Of this, the enabled revenues for intermediate users amount to between EUR 365 million and EUR 798 million while those for the end users are estimated at between EUR 119 million and EUR 2337 million. This important difference is due to the analysis of two different scenarios: a minimal estimation very conservative based on case study only and an optimistic scenario based on the extrapolation of the results from, the case study to larger markets. In terms of employment, Copernicus is forecast to support a cumulative total of **between 3,050 and 12,450 person years over 2015-2020**.
The key features and benefits for each value chain are presented below.

Agriculture

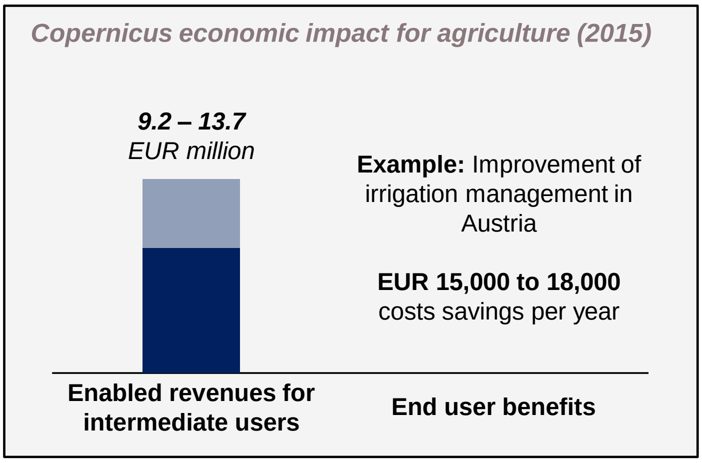
Historically, agriculture was one of the first domains to leverage space-enabled EO data and services. Indeed, the first EO-based applications for precision farming techniques were developed in the 1990s. Today, **a majority (approximately 90%) of EO applications in the agricultural sector focus on precision farming**. In 2015, agriculture was the fifth out of 22 sectors in terms of revenues in the EO market. The EO downstream market for precision farming applications is estimated at EUR 66.30 million (2015).
Other applications in agriculture are:

- enabling farmers to **make an improved selection of the crop area** by providing information about soil properties
- providing maps to public authorities of cultivated areas by crop type from local to national level by the mid or the end of the crop season
- contributing to more efficient water management and drought monitoring
- supporting the **preparation of subsidy controls** to reduce risks as the controls are applied

The Copernicus Land Monitoring Service provides useful and important information to intermediate and end users in agriculture. It provides geographical information on land cover and on indicators related for instance to the water cycle. It consists of three main components: a global component, which produces data across a wide range of biophysical variables describing the state of the vegetation, the energy budget and the water cycle; a pan-European component which produces five high resolution data sets describing the main land cover types; a local component, providing specific and more detailed information focusing on land cover and usage.

Intermediate users are very heterogeneous, encompassing start-ups and SMEs, larger players such as Airbus geoinformation, and pure scientific players such as research organisations and universities. The EO market for agricultural-focused products is rather fragmented with many service providers focusing on niche sectors. Opportunities in developing countries are expected to grow due to the pressing challenges related to food security.

End users include both public actors (such as government authorities needing precise information to implement specific policies and regulations, or development agencies and donors seeking to monitor specific issues such as food security or the impact of droughts), and private actors (agricultural corporations, food companies, etc.). **Agricultural end users benefit greatly from the Copernicus programme**. Some farmers for example have increased their productivity by around 20% thanks to applications based on Copernicus data (among other types of data), while other applications have enabled them to save 20% of their water resources by more efficient irrigation management.



All the stakeholders interviewed in this study currently use Sentinel-1 & 2 data. The current enabled revenues from the precision farming European market directly attributed to **Copernicus represent 2.49% (conservative estimate) of total revenues in the European precision farming market, corresponding to approximately EUR 9.21 million**. A **higher estimate would include the GIS market and would be approximately EUR 13.69 million.** The contribution of Copernicus to overall enabled revenues is expected to rise in the coming 5 to 10 years, based on stakeholder consultation. Revenues directly attributable to Copernicus are expected to amount to approximately 17% of the service providers' overall revenues in 2020, corresponding to EUR 37.70 million (conservative estimate). When considering the GIS market rather than the EO market, a higher estimate of the revenues directly attributable to Copernicus in 2020 would amount to EUR 78.24 million.

In terms of **non-monetary benefits**, applications that support greater focus in the use of agricultural inputs have positive environmental impacts. In terms of social impacts, precision farming techniques enable farmers to reduce the use of inputs in food that pose risks to human health.

Case study: Copernicus is contributing to a service based on EO data to improve irrigation management in lower Austria, developed by the Institute of Surveying, Remote Sensing and Land Information in the University of Natural Resources and Life Sciences of Vienna. The specific services are: crop development maps (available every 7 to 10 days), evapotranspiration maps, information and weather data and forecast delivered daily, as well as specific irrigation requirements depending on crop types.
The integration of Sentinel data has reduced the total service cost by 23%. This service has also shown potential economic benefits for the end users: 54% of farmers expressed a general willingness to pay, and service would cost about EUR 1.25 per hectare per years with Sentinel data whereas it costs between EUR 3 and 5 per hectare per year with commercial data.

Forestry

Forests are multi-faceted natural resources. In 2008, the wood-based manufacturing industry in the EU employed about 2.8 million people, generating a turnover of more than EUR 400 billion. The forestry domain exhibits governance models that differ from one country to another: in some parts of the world, the majority of forestry owners are from the private sector (e.g. Austria, Finland, France, Slovenia) whereas in other countries (e.g. Bulgaria, Poland Romania, Sweden), most forests are publicly managed. The EO downstream market for forestry is estimated at EUR 36 million (2015). EO data has a recognised added-value in the forestry sector and is used to develop various services:

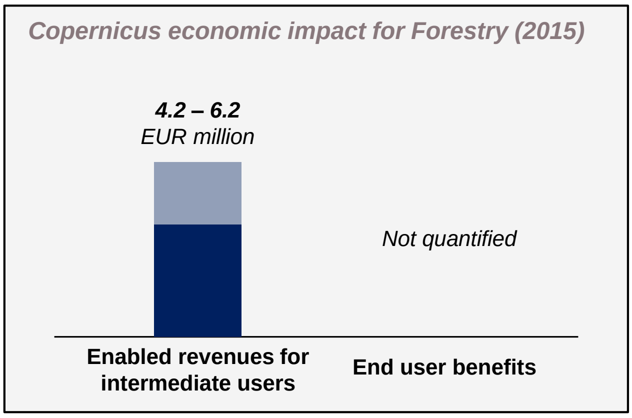
- providing a panoptic view of forest mapping and forest change mapping, particularly to produce maps supporting the preparation of **National Forest Inventories (NFIs)**
- monitoring **illegal logging** of forests by comparing high-resolution maps of forests to monitor changes in forest coverage and identify illegal cuts
- identifying and monitoring **forest fires** in near-real time
- preparing different types of **cartographies of forest biophysical variables** for example, representing the volume of trees to optimise forestry harvests
- supporting **more sustainable forest management,** in particular in the context of the UN Reducing Emissions from Deforestation and Forest Degradation (REDD+) programme, aiming at mitigating the impacts of global warming on forests.

The **Copernicus Land Core Service** develops several products which may be relevant for forestry, even though it is not dedicated to this particular theme. It provides products that are used by forestry intermediate and end users, under the pan-European service. Products provided by the Land Core Service focus on two main issues: tree density and forest type.

Intermediate users of EO data in forestry are quite heterogeneous: they include several private actors – with 34 European companies (from micro-companies to larger players) developing VAS on forestry-related issues, the forestry sector is the fourth most important sector in terms of number of companies active in Europe – as well as public research institutions and forestry management organisations.

Among end users, forestry-targeted EO products are currently used mainly by **public end users (90%)**, rather than **private end users (10%)**. Demand comes from public organisations eager to integrate EO-based services to support their activities. Historically the forestry value chain has suffered from the limited time span of EO projects and/or applications based on EO data, because such projects are funded by public stakeholders with limited timeframes.

The methodology used to calculate the Copernicus current enabled revenues was as follows: firstly, 90% of the stakeholders interviewed within this assessment currently use Copernicus data to develop forestry-related products. Copernicus currently contributes some 11.50% of the total amount of EO data used (conservative estimate). Hence, **a conservative estimate of the value of Copernicus data to forestry management is just under EUR 4.20 million in 2015**. The projected contribution of Copernicus to global and European socio-economic impacts is expected to grow and



reach approximately EUR 7.60 million in 2020 (conservative estimate). A high estimate, based on the GIS market, suggests that the enabled revenues of Copernicus could be some EUR 6.21 million in 2015 rising to EUR 15.81 million in 2020.

In terms of non-monetary benefits, the availability of Copernicus data has promoted an increase in the knowledge and competence in-house of service providers. In addition, Sentinel data helps to curb negative environmental impacts by improving the monitoring of deforestation.

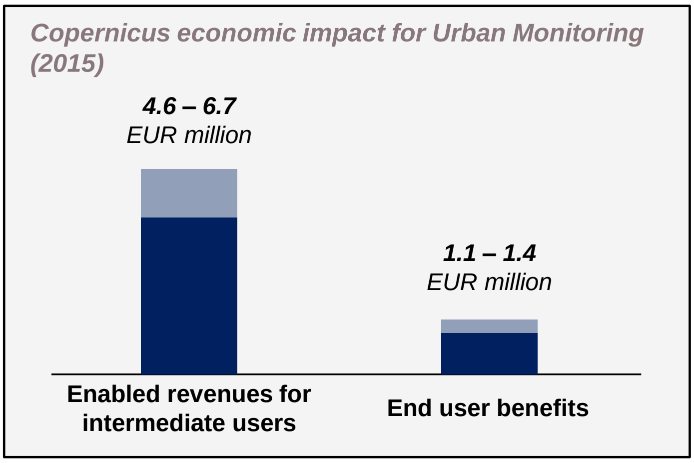
Case study: Copernicus is key in ESA's Forestry Thematic Exploitation Platform. A pilot project has been launched in Mexico to support forest mapping in the framework of the REDD programme. Previously, forest mapping was undertaken by field inspections only. The integration of Sentinel 1 and 2 data will be gradual. The objective is for Sentinel-2 to account for up to 90% of the whole amount of data processed. In addition, it is expected that Sentinel-2 data will significantly improve the quality of forest mapping, for example in the identification of tree species. Since all the stakeholders involved in this project are from the public sector, the majority of the projected impacts are qualitative (because there is no market value for their activities).

Urban monitoring

Some 54% of the world's population lives in urban areas in 2014, and this proportion is expected to reach 66% in 2050. As cities grow and expand, their management, governance and the provision of services become increasingly complex. **The EO market for urban management is estimated at EUR 45.50 million (2015)**, five times its estimated size of EUR 7.86 million in 2012. The added value of EO data in urban management and planning lies in the data it provides for various urban indicators (socio-economic, climate or geographic).
The main applications based on EO data in the urban monitoring sector are:
Applications linked to risk management to detect impervious surfaces and structure instability issues
Applications which focus on environmental and health impact management
In the field of socio-economic impact management, EO-based applications provide information on access to public services and networks and population density
Regarding city planning, applications provide mapping, routes for transport, urban sprawl
In terms of market research, several EO-based applications focus on the detection and analysis of construction sites and the identification of sites for new stores.

The **Copernicus Land Monitoring Service (CLMS)** is coordinated by the European Environment Agency and comprises four main components: global, pan-European, local and in situ. The pan-European component and the local are the most relevant for cities, whereas the global is oriented towards vegetation, water cycle and energy budget. The Pan-European components include products such as **Corine Land Cover** which consists of an inventory of land cover with 44 classes. The Local component includes products such as **Urban Atlas**, which has detailed land cover and land use information for major EU city areas.

Intermediate users are from both the private and the public sector. On the institutional side, the main intermediate users are environmental agencies such as the European Environmental Agency (EEA). On the commercial side, VAS companies operating urban services are often working on land and agriculture in general: examples in Europe include GIM or Geoville and more diversified VAS players like Indra. Earth-I.



End users are mostly in the public sector – the main end users are **local authorities** (e.g. urban planners, city administrators, transport authorities). Other public users are **national governments** (for land administration for instance), **NGOs** (for slum mapping for example), and **international organisations** (e.g. World Bank, EuroGeographics representing the European National Mapping, Cadastral and Land Registry Authorities).

A conservative estimate of the value attributable to Copernicus data within urban monitoring is EUR 4.55 million (2015) but this estimate is likely to be a lower bound. Copernicus data is typically valued more highly than non-Copernicus EO data. The use of Sentinel-1 data has generally required investments in specific hardware and software and highly skilled workers. The highest estimate of the enabled revenues directly attributable to Copernicus would include the impact on the GIS market and would amount to EUR 6.69 million. On top of these enabled revenues, Copernicus has a strong network effect and is generally considered as a competitive advantage in a sales pitch to local authorities made by intermediate actors.

Regarding the direct impacts on the end users, a Cisco study shoes that for a city of 1.20 million inhabitants, the ROI of investment in smart cities products is of 25%. Considering that the investments of end users in Copernicus products does not exceed their corresponding revenues and that these investments equal the Copernicus enabled revenues for the downstream sector, the Copernicus enabled revenues for end users are estimated to be of around EUR 1.14 million (conservative estimation) and EUR 1.42 (optimistic estimation).

Case study: Copernicus is used by the German start-up Building Radar for early detection and remote monitoring of construction sites. Copernicus accounts for 60% of the satellite data used by this VAS company. Today, 40% of their clients use applications which rely on Copernicus data. Hence, the minimum monthly turnover directly attributable to Copernicus is some EUR 4,000 (40% of their minimum turnover estimate). The applications developed by Building Radar have important benefits for end users: on average, for all their applications and types of clients, Building Radar enables its users to save 3 hours per day and EUR 60,000 per year.

Insurance

With an average in excess of EUR 150 billion of losses per year, natural disasters represent a growing threat all over the world, in both developed and developing countries. In Europe, natural hazards represented approximately EUR 12 to 13 billion of losses and over 8000 casualties per year over the 1998 – 2009 period. The hazards with the largest impact are floods, which accounted for more than one third of the total losses. European property insurance premiums amounted to EUR 92 billion in 2014, up by 2% on the 2013 value. Insurance related to natural disasters covers about 30% of the total losses, and relies on EO both to anticipate catastrophic events and assess the damages or state of insured assets after the event. Currently satellite images are used for 3 types of activities:

Risk modelling involves evaluating the potential losses that could arise due to natural disasters through a probabilistic assessment of events. By improving the accuracy of the predictions, (re)insurers are able to better forecast cash out-flows and reduce the financial risks, eventually reducing premiums. EO data is used as a complementary source of information to meteorological and geological data, and generates a moderate added value. It contributes to the calibration and the validation of the risk models of (re)insurers and external catastrophe modelling companies. Copernicus offers a good contribution to these activities with its large scope, its reliable and trusted data and its open data policy.

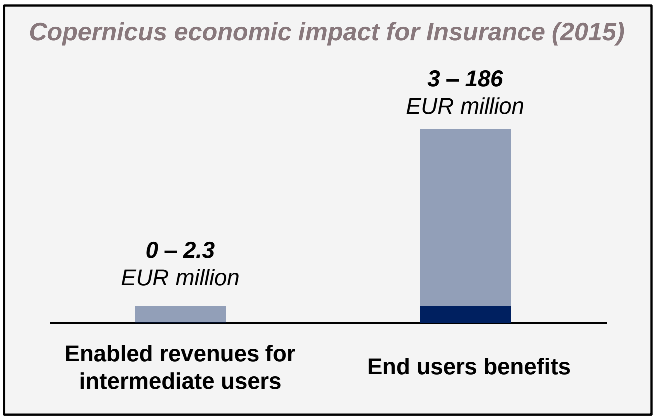
Loss assessment involves comparing the claims received from clients with the actual material damages that occurred in the field in order to determine the amount of compensation that should be paid. EO data provides a visualisation of the extent of the damage (production of delineation maps) and helps to optimise intervention, reducing costs for insurers. Copernicus is used for some large-scale events, but responsiveness and high resolution can be important factors in the choice of EO source and commercial satellites are often selected to obtain the images, reducing the overall contribution of Sentinels data.

Index products are a more recent offer and rely exclusively on satellite images. Based on the regular monitoring of areas to compute a numerical index, it is particularly useful for crops and livestock insurance. These products are an alternative to traditional insurance approaches, and allow new markets (farmers and pastors) to be addressed, especially in remote areas. Copernicus is a good candidate for this application because of its particular capabilities, including good resolution, revisit frequency, certified data and open data policy. The main barrier to its use is the long history required for the computation of an accurate index.

Among the core services of Copernicus, the **Copernicus Emergency Management Service (CEMS) – Mapping** provides two types of on-demand services, for fast provision after an event and for activities which are not related to immediate response. These services provide geospatial information derived from satellite data (supplemented by other sources, such as in situ data) to actors involved in the management of natural disaster emergencies.

The **main intermediate users are very large insurers and reinsurers** with in-house capabilities (Munich Re, Swiss Re, Willis Re, AXA…) and also smaller VAS companies.

The **main end users** in the insurance value chain are reinsurers and insurers. Other actors can be individuals and businesses which benefit from EO exploitation through better disaster forecasts. Farmers insured by index products are directly able to access new, innovative products. As well as insurance products, satellite images of catastrophes also provide important benefits to public entities, especially civil protection teams and emergency services.



There is wide variation in the take-up of EO processes within (re)insurers and it is therefore difficult to establish a global figure for the European market. For 2015, **the Copernicus-enabled revenues for the downstream sector for insurance can be estimated between 0 (conservative estimate) and EUR 2.25 million (high estimate)**. Looking forward, the revenues enabled by Copernicus are expected to reach between EUR 0.10 million and EUR 27.15 million in 2020. The revenues from index products should start growing after 2020, when about 10 years of data history will be available. Bearing in mind that other sources might remain preferred for data continuity issues, the total European market can be broadly estimated at around EUR 500 million in 2015 (stable), highlighting a real opportunity for Sentinels data to contribute to the European insurance sector. Regarding the economic impacts of the Copernicus programme for end users, there is a large difference between minimal and high estimates: in 2015, they range between EUR 2.90 million and EUR 186 million. The conservative estimate was calculated based on the stakeholder consultation whereas the high estimate was calculated taking into account the global revenues from the insurance sector and the potential impact of Copernicus.

Alongside the economic impacts, Copernicus data also offers social benefits by improving the insurers' level of service towards their clients. In the future, Copernicus will also contribute, through index products, to the coverage of remote farmers in developing countries where traditional insurance schemes are not viable, offering cover for business risks and ab improved standard of lviing. In addition, Copernicus' reliable data offers a complementary source for emergency services during intervention following a catastrophe, providing strategic information in these critical situations, and also benefits to the scientific community for the monitoring, studying and understanding of natural disasters.

Case study: Agroseguro, a Spanish company, uses the EO-based Normalised Difference Vegetation Index (NDVI) to manage agricultural insurance on behalf of its shareholder insurance companies. A broad estimate of the potential market value for livestock index insurance in Europe can be made at EUR 516 million. Considering that Sentinels' share of EO sources for index insurance would have been around one third of the total in 2012, the revenues enabled by Copernicus are estimated at around EUR 172 million.

Ocean monitoring

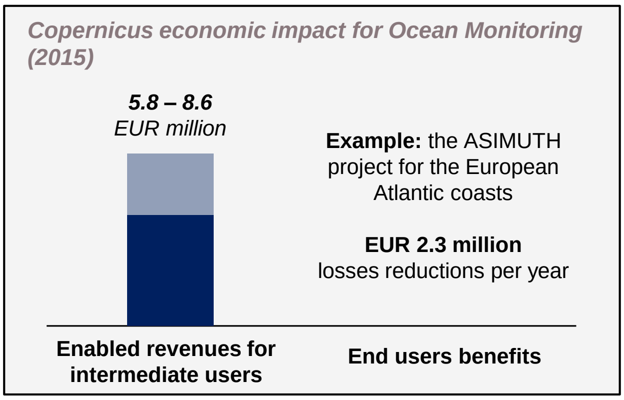
The ocean is a global economic resource. In Europe, fishing and fish processing activities provide jobs for more than 350,000 workers. The ocean monitoring domain encompasses a wide range of activities encompassing very different needs: these include sustainable fishing and the protection of marine resources, ocean surveillance and coastal protection, extraction of natural resources (minerals, energy, etc.), commerce and trade.
Ocean monitoring represents one of the most important sectors by revenue in the European EO market, at some EUR 103 billion in 2015.
EO contributes in particular to the following applications:
Aquaculture and fisheries: the use of EO data is especially useful for mapping fishing zones.
Improve practices for the **protection of aquatic species and marine biodiversity** by assessing the biological characteristics of the ocean
Coastal protection through the monitoring and prevention of coastal erosion
Monitoring Harmful Algal Blooms via specific monitoring systems
Monitoring reef ecosystems in order to limit the detrimental effects on coral reefs and prevent their degradation

The **Copernicus Marine Environment Monitoring Service (CMEMS)** has substantially boosted the uptake of EO data among stakeholders engaged in ocean-related matters. It is estimated to have **between 5,000 and 6,000 users, 80% of which are from the public sector**. This core service provides a sustained response to European user needs in four main areas: maritime safety, marine resources, coastal and marine environment and weather (forecasting and climate). It provides regular reference information on the state of oceans and regional seas through the production of observations (description of the current analysis), forecasts (the prediction of the situation a few days ahead) and re-analysis (the provision of consistent retrospective data records for recent years).

Intermediate users of EO data related to ocean monitoring comprise a small number of large players with a large market share, and a larger number of smaller players (micro companies and SMEs) together with public institutions, such as laboratories.

End users of applications based on EO data are both from the public sector (ministries, local governments, laboratories, sea authority centres, authorities in charge of marine conservation) and the private sector (fish farmers, etc.). There are growing opportunities for EO projects and services in countries outside of Europe concerned about specific ocean-monitoring issues (like Indonesia, which has a pressing need to monitor fishing and marine biodiversity).

The Copernicus current enabled revenues account for 5.55% of the EO downstream market for ocean monitoring, corresponding to EUR 5.76 million, and could reach EUR 27.89 million in 2020 (conservative estimate). A high estimate (including the GIS market) values the market now at EUR 8.55 million and EUR 58.02 million in 2020. Just 16% of the stakeholders interviewed have indicated that they currently use Sentinel-1 and/or 2 data. In terms of economic impacts, Copernicus data has enabled several service providers to decrease slightly their production costs by replacing data bought from private satellites with free Sentinel data. A significant boost to the enabled revenues from Copernicus is expected to occur with the availability of Sentinel-3 data, which will be particularly relevant by providing information on sea surface height, ocean colour, sea surface temperature, tracking of wind and waves, etc.



In terms of **non-monetary benefits**, the integration of Copernicus data contributes to sustainable fishing and limits environmental degradation.

Case study: The ASIMUTH project seeks to forecast Harmful Algal Blooms for fish and shellfish farmers in Europe. Harmful Algal Blooms produce toxins and can have negative impacts on the environment. The Copernicus programme was a cornerstone for this project, which has raised the productivity of fish farmers by approximately 5%. Looking forward, the forecasting system implemented within the ASIMUTH project should contribute to reduce the losses caused to the mussel industry by at least 12.5% in five target countries: France, Spain, the UK, Ireland and Portugal.

Oil and gas

The O&G value chain is, among the ones chosen for the study, one of the **most commercially-oriented**. The analysis carried out in this value chain focuses on private end users from the upstream O&G industry. While several public end users are also involved in this market (governmental agencies in charge of surveying prospective areas for exploration and mapping national resources, governmental agencies in charge of oil spill monitoring and oil spill response, etc.) only private end users were considered in the analysis, in order to maintain a stronger focus on commercially-driven activities and on enabled revenues.

Based on EARSC data (2015), more than 8% of the EUR 911 million revenues of the European EO downstream industry are derived from the O&G industry, representing around EUR 73 million. Sales of EO data and related products and services have dropped by 19.24% from 2012 to 2015 while overall EO downstream sales have increased by 13.72% over the same period: the **main driver for the market is the price of oil** which has fallen sharply since June 2014.

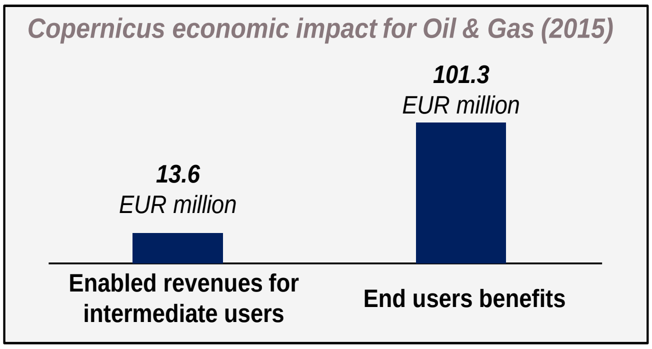
The main applications based on EO data focusing on oil and gas are as follows:

- Maps and indicators to support exploration and drilling activities

- Indicators for **environmental monitoring** (e.g. coastal ecosystem, marine habitats, pollution at sea, etc.)
- Maps and indicators to support **transport and logistics** (e.g. forecasts of current movement and drift)
- Maps and indicators to prevent **risks of disasters** (e.g. maps of flooding, detection of hurricanes and typhoons, etc.)
- Maps and indicators to support **infrastructure construction and safety** (e.g. maps to monitor construction and buildings, maps of large waves, indicators to monitor oil rigs and flares, etc.)

The usage of EO data within the O&G upstream industry varies considerably from one actor to another but, in general, the use of EO is quite widespread among upstream O&G end users compared to other mostly commercially-driven value-chains. Major companies are the main players in the O&G upstream industry – they are also the main players in the midstream and downstream industries – and they are clients of all the other services (oilfield services and environmental services). All exploration activities are performed by the operators which buy prospection areas and perform most of the activities in-house. For very specific activities such as exploratory drilling or ex-ante environmental impact monitoring, they rely on outside companies performing oilfield and environmental services. The market is very well organised, very rational and very conservative.

O&G represents a significant stream of revenues for European EO downstream players; however, the largest value is ultimately created by the O&G end users. The largest share of value derived from the Copernicus data and products in the sample under scrutiny is derived from O&G end users, and not from intermediate users. Most of the industry has already switched to the GIS products & services. Upstream O&G actors are in most cases using imagery incorporated in more complex GIS products, including EO (all resolution), UAVs data (when national regulation allows it use), in-situ data, internal data and statistics, etc.



Of the sectors reviewed in this study, the O&G value chain has the highest level of enabled revenues currently associated with the Copernicus programme. **The current value of Copernicus data for the upstream O&G industry is estimated at least to be EUR 8.75 million in 2015 (conservative estimate based on a case study)**, **with an overall market estimated around EUR 115 million**. The second scenario was assessed using the results from the case study and then extrapolated to the size of the European O&G upstream market. According to Technavio, the O&G revenues in the European GIS market amounted to EUR 97.19 million in 2015. Current revenues enabled by the availability of Copernicus data seem to be low. This can be explained by the fact that the current price of oil inhibits take-up of Copernicus data and EO products within O&G activities. It is also still too early to assess the genuine scope for enabled revenues since many stakeholders have faced issues in accessing Copernicus data. The potential value of Copernicus data for the upstream O&G industry is projected to be at least at EUR 33 million by 2020 (conservative estimate), up to EUR 312 million (extrapolated value).

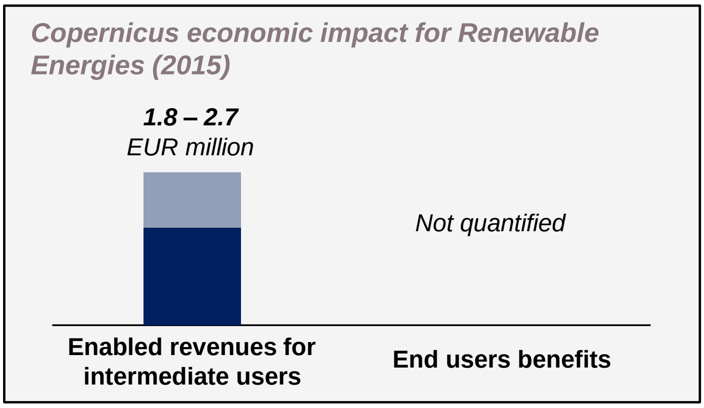
Case study: The EO4OG project was launched following discussions between ESA, EARSC and the International Association of Oil and Gas Producers (IOGP), in an effort to develop new collaborations to bring together EO and O&G communities. The objective was to solve new challenges faced by the O&G industry. The assessment of the Copernicus socio-economic impacts noted above was derived from a case study of the Earth Observation for Oil & Gas (EO4OG) project because it is the most comprehensive initiative in Europe to promote take-up of EO data by the O&G industry.

Renewable Energies

Today, renewable energies globally employ around 8.10 million people. The European renewable energy industry is reported to have generated some EUR 130 billion turnover in the EU in 2012. Solar, wind, hydro and biomass renewable energy sources (RES) represent about 98% of the estimated renewable energy electricity production and at least 70% of the renewable energy consumption. Between 2004 and 2014, the total supply of renewable energies has increased by 30%.
The market for commercial applications of EO downstream services in the renewable energy sector is rather new, and its size was estimated to be approximately EUR 18 million in 2015.
EO-based applications contribute to renewable energies products in various ways:

- **Site selection** and design of plants or facilities
- Production efficiency monitoring
- Energy production forecasting
- Energy trading
- Environment monitoring
- **Identifying biomass** and monitoring production

Three of the Copernicus core services provide products that are useful for renewable energies: **Copernicus Land Monitoring Service (CLMS)** provides global observation for **wind characteristics**. The Copernicus Marine Environment Monitoring Service (CMEMS) provides information on sea surface winds. Finally, the **Copernicus Atmosphere Monitoring Service (CAMS)** has enabled so far the development of products encompassing time-series of **solar radiation** reaching the Earth's surface in periods of good (bright) weather, the calculation of surface solar irradiance and the monitoring of weather uncertainties affecting solar radiation conditions (e.g. clouds, aerosols, water vapour and ozone).



The **main intermediate users** in Europe in the field of renewable energies are VAS companies or research centres. The VAS companies are SMEs that are specialised in a type of EO product, as for example in the cases of Rezatec operating in land-based asset management through EO, or TRE, specialised in deformation detection. Regarding solar energy, most of the intermediate users are SMEs, experts in the sector, which provide services to solar power generators and have begun to use EO data to improve their products. In Europe, the main VAS companies producing PV energy forecasts are the SMEs Reuniwatt and SteadySun.
A conservative estimate of the revenues enabled by Copernicus for the global renewable energies market is of EUR 1.82 million in 2015, corresponding to 8.01% of the EO downstream market for renewable energies in Europe. The current enabled revenues correspond to a combination of the total sales of products/ service from suppliers to renewable energy generators that are enabled by services / products developed by VAS companies and the increase in revenues for the renewable energy generators enabled by Copernicus products.

In terms of **end users**, energy providers and electricity grid managers are the main end users of EO products related to renewable energies. On the public sector side, state and local decision makers also benefit from EO related products, and so do renewable energy agencies and municipalities.

In terms of the non-monetary benefits, the Copernicus programme creates jobs in the renewable energies sector. Throughout the monitoring of biomass, Copernicus also helps to reduce the emissions of greenhouse gases by supporting the production of biomass. In parallel, the Copernicus Land Service contributes to the monitoring of land use and creates a balance between agriculture, biomass and solar farms.

Case study: Reuniwatt, a French SME, uses Copernicus to monitor solar panels. Its main product is Soleka, which forecasts solar power production for electricity grid managers and photovoltaic (PV) electricity producers to facilitate the introduction of renewable energy in the power supply mix and to detect faults early. This product delivers forecasts with three different temporal horizons: T+ 30 min, H+6 hours and H+24 hours. For H+24 forecasts, adding Copernicus data improves the quality of the forecasts by 30%. In addition, Reuniwatt demonstrated that the use of Copernicus and satellite-based forecasts provides a benefit of up to 50% in terms of PV production economic value for the H+24 h meteorological forecast. For the T+30 and H+6 products, Reuniwatt estimates the reduction of costs being of 15% since it saves time in their data processing.

Air quality

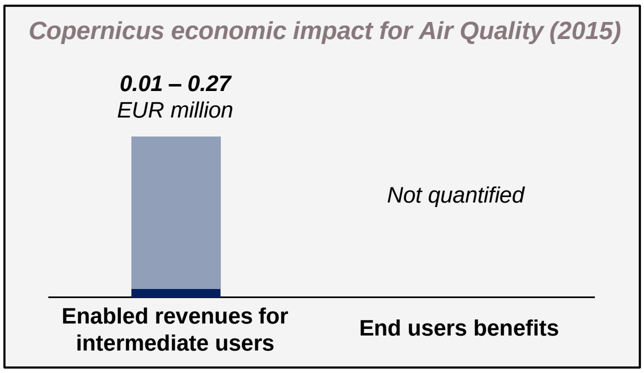
Air pollution is among the major challenges of the 21st century, having an unprecedented impact on human health, climate and ecosystems. In 2013, around 5.50 million people died as a result of air pollution. The economic impact associated with air pollution is significant. In 2010, it represented EUR 15 billion from lost work days, EUR 4 billion from healthcare costs, EUR 3 billion from crop yield loss and EUR 1 billion from damage to buildings in the EU alone.

The commercial market for air quality applications is rather small: **in 2015, it is estimated at 1.82 million, corresponding to 0.20% of the overall EO downstream market in Europe**. This can be explained by a lack of willingness to pay or lack of budget available from end users and by the fact that air quality analysis is in some cases carried out by public authorities. Furthermore, EO data for atmospheric composition has only recently been introduced into air quality analysis models; these models have traditionally been based on meteorological data, air composition statistical data and measurements. Indeed, ENVISAT is the only satellite which has managed successfully to provide relevant information for the monitoring of air quality at the beginning of the 2000s.

The main EO based applications focusing on air quality are as follows:

- **Urban air** nowcasting and forecasting
- Pollutant fluxes tracking
- **Local scale** air quality analysis
- **Hotspots** detection

Most of the **intermediate users** of the air quality sector do not download directly Sentinels data but use the **Copernicus Atmospheric Monitoring Service (CAMS)**. Most CAMS users are based in Europe and are mainly **European-level decision makers** (national governments, regional authorities, environmental institutions). They use the CAMS European scale model to feed their own models. **Copernicus Land Monitoring Service (CLMS),** and in particular CORINE Land Cover, can also be used as input data for the air quality forecasting models for cities, providing geographic data, or for identifying potential pollution sources. **Intermediate users** are mainly meteorological and environmental agencies or publicly-funded organisations such as associations; however an increasing number of VAS companies are entering the market with air forecasting products. Analysing air quality requires numerical models and the EO data is one of the inputs used in such models.



In order to assess the revenues directly attributable to Copernicus, it is necessary to isolate the portion of the EO downstream market revenues for air quality which corresponds to private actors. Assuming that the distribution of Copernicus users between public and private actors is similar to that for the EO market in the field of air quality (20% of public actors versus 80% of private actors), the EO revenues generated by private actors are estimated at EUR 364,000. The companies consulted for this analysis have estimated that between 3% and 10% of their revenues associated with air quality products and services can be attributed to the enabling role of Copernicus. Hence, **revenues generated by Copernicus in the field of air quality are quite limited and are estimated to range between EUR 10,900 and EUR 36,400 (conservative estimate)**. These revenues are expected to grow in the coming years with an increase in the penetration in the municipalities market and a boost of the number of actors wanting to buy air quality forecasts. A high estimate would take into account the impacts on the GIS market and the revenues would correspond to EUR 270,000 in 2015.

The end users are mainly local authorities that want to monitor the air quality in their territory and implement the appropriate policies for traffic regulation, private companies such as waste management companies, individuals who want to be aware of the risks related to air pollution, and research companies who need to better understand the climate and past greenhouse gas trends. Though they are not quantified here, there are also benefits for end users, linked to the impact of air pollution such as sick leaves, healthcare costs etc.

In terms of non-monetary benefits, better monitoring air quality reduces the negative impacts on ecosystems, animals and infrastructure and can also help to save millions of lives. Copernicus brings a qualitative appreciation of air quality. It provides coverage in zones where there is no in situ data.

Case study: A more in-depth analysis of Copernicus socio-economic impacts was performed for the Urban Air application developed by a French start-up, NUMTECH, developing value added services in the field of air quality. NUMTECH started using Copernicus three years ago for the Urban Air product, which provides high resolution air quality analysis for cities. Thanks to Copernicus, NUMTECH was able to monitor some pollutants such as particulates matter for which non-local emissions can greatly contribute to local concentrations. In this specific case, the precision of the Urban Air product was improved by 60%. For other local pollutants, the improvement of the precision can be assessed at around 10% to 20%.

Part (e) – Overall assessment of the Copernicus downstream sector and end users

A survey was conducted by the European Commission to collect the opinion of EO companies regarding the barriers to the exploitation of Copernicus data. The key results of this survey are:

- Difficulties regarding access, downloading and predictability of the availability of the Copernicus data
- Difficulties linked to market characteristics, in the sense that potential end users are not sufficiently aware of the benefits of EO products, a lack of financial support, etc.
- The added-value of initiatives to foster international development, such as events combining both customers and partners, etc.

The combination of the survey, on the one hand, and the extensive stakeholder consultation, on the other, identified general strengths, weaknesses, opportunities and threats (SWOT) of the Copernicus programme, as set out below:

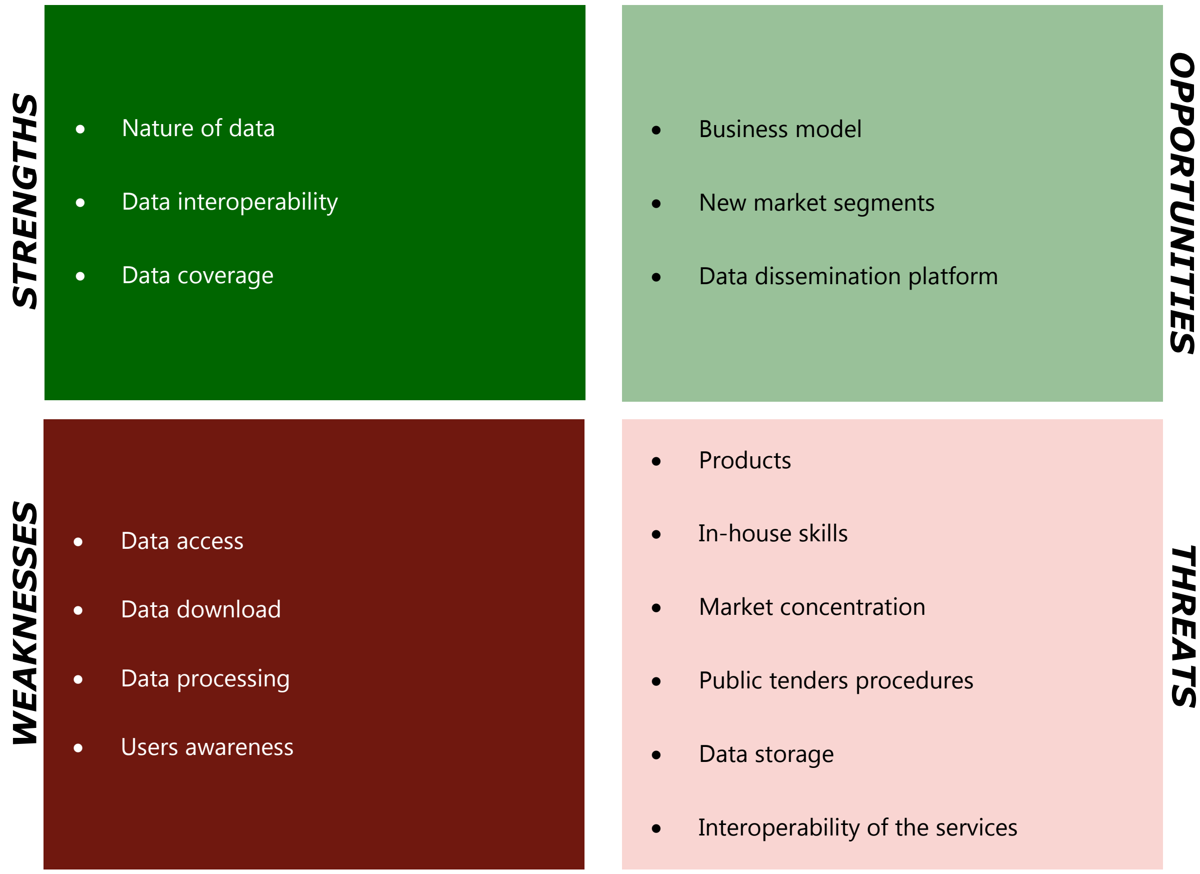


Figure 3: Synthesis of Copernicus main Strengths-Weaknesses-Opportunities-Threats (SWOT) (Source: expert consultation; PwC-Strategy& analysis)

Copernicus' main strengths

Nature of data: The continuity, availability, accuracy, reliability of the Sentinels data, compared to competing programmes, provides a tangible added value.
Data interoperability: The combination of Sentinels data with other types of data allows generalisation from detailed studies which leads to many developments.
Data coverage: The worldwide data coverage of the Copernicus programme represents a lever for companies working on a global scale and expanding.

Copernicus' main weaknesses

Data access: The accessing of Sentinels data is not regarded as intuitive unless stakeholders are familiar with the EO eco-system and the platforms rarely focus on the user's needs and specificities.
Data download: The administrative application is considered too complex and detailed and entire data sets need to be downloaded when just a few images may be sufficient.
Data processing: The large volume of data and its complexity implies huge computation capabilities which are considered expensive and time-consuming.
Users awareness: EO applications are a niche market. Current users consider that there is a real need to raise awareness among the potential users, who do not see the added value of applications based on Copernicus data.

Copernicus' main opportunities

Business model: Copernicus' Open Data policy is a lever for innovation as free data access supports the presentation of proofs of concept for new applications.
New market segments: There are huge opportunities to address new end users' needs, especially public authorities' needs and the developing countries' issues. New sectors (e.g. tourism, gaming, etc.) could also benefit from EO, and thus from Copernicus data.
Data dissemination platforms: By capitalising on existing infrastructures (such as platforms), Copernicus data dissemination could be leveraged.

Copernicus main threats

Products: End users underlined a gap between their needs and the products and services currently offered by intermediate users.
In-house skills: Copernicus data is currently mainly used by the scientific community. Potential users are reluctant to use space solutions, as it requires expensive and time-consuming trainings for non EO-experts.
Market concentration: The EO market has a substantial barrier to entry, namely the level of the required capacity to understand, compute and use EO data, and so large firms have a strong influence in the market, and they have the power to acquire disruptive start-ups.
Public tenders procedures: Copernicus intermediate users, especially SMEs, expressed the view that the applications for H2020 calls are too time-consuming. The grading system also seems quite misunderstood. Ultimately , there is a risk that it might curb innovation rather than speeding it up.
Data storage: Only a few stakeholders have the capacity to store large volumes of data. In the medium term, the risk is that only a small number of data providers will offer archived Sentinels data, which will unbalance the market and go against the Open Data policy.
Interoperability of the services: Currently the different Copernicus services are working too much in silos and not enough in a cross-services desig which is a barrier to maximum efficiency in these services.

General recommendations

The in-depth analysis of the value chains, throughout the stakeholders' consultation, the extensive literature review and the survey has led to the formulation of a number of policy recommendations classified in three main pillars: Ensure access to data (Pillar I); Support Innovation (Pillar II); Increase awareness and use (Pillar III).

Main recommendations expressed by public intermediate users (sample=24)

	Stakeholders review		PwC – Strategy& Analysis				
Strategic pillar	***Transverse recommendations for policy action***	***Recurrence among users***	***Feasibility***	***Financial Affordability***	***Quickness***	***Strategic Impact***	***Overall priority level***
***Pillar II:* Support innovation**	***#PUB-1 – Prompt innovation through hackathons and demonstrators*** Today, the "killer app" which will revolutionise the market has not yet been found. **Hackathons and demonstrators still have to be organised to lead to viable applications.**	2	●	●	●	◕	1
***Pillar I:* Ensure access to data**	***#PUB-2 – Address the non EO-literate users through dedicated tutorials*** EO data is mainly used by the scientific community as it is still difficult to manipulate. **The EC should provide basic tutorials to facilitate the undertaking of EO data by non EO-experts.**	3	●	●	●	◔	1
***Pillar III:* Increase awareness and use**	***#PUB-3 – Focus on local authorities*** There is a lack of awareness among local authorities. The EO applications could have a huge impact at local scale. **It could be relevant to classify the Copernicus data by territory and to gather feedback from such potential local users. The EC could also present best practice and examples of applications for local situations.**	3	◕	◕	◔	●	2

Main recommendations expressed by private intermediate users (sample=52)

	Stakeholders review		PwC – Strategy& Analysis				
Strategic pillar	***Transverse recommendations for policy action***	***Recurrence among users***	***Feasibility***	***Financial Affordability***	***Quickness***	***Strategic Impact***	***Overall priority level***
***Pillar II:* Support innovation**	***#PRI-1 – Build common standards*** Private intermediate users are expecting **real-time data** and **a standard of low resolution processed data** furnished by the Copernicus core services to avoid duplication of basic computing work, save time and enable easy comparisons.	1	◔	◕	◔	●	3
***Pillar II:* Support innovation**	***#PRI-2 – Balance the open data communication*** The open data policy is key and supports the building of disruptive products in viable business models but it can also threaten some commercial services. In the current digital trend, end users are now expecting applications and services for free and do not take into account the underlying added value work. **The wording of the institutional communication should take care to avoid confusion between open data and free enabled services.**	2	●	●	●	◔	1
***Pillar I:* Ensure access to data**	***#PRI-3 – Simplify and harmonize the data access infrastructure*** Accessing Copernicus data is a significant issue. The multiplicity of access points does not ease the work of non-data specialists. Private intermediate users welcome having such a large choice. Hence, **the**	3	◔	◔	◔	●	3

	data access infrastructure should be harmonized and simplified in order to facilitate data access by end users.						
Pillar III: ***Increase awareness and use***	***#PRI-4 – Appeal potential end users*** Most end users are not aware of EO data potential. **A marketing campaign underlining the savings induced by Copernicus applications based on concrete case studies would be relevant.**	3	●	●	●	◕	1
Pillar I: ***Ensure access to data***	***#PRI-5 – Propose data computation services on-line*** Due to its huge volume, Copernicus data is complicated to process and store, thus requiring large investments. **Providing basic on-line computation services will ease this problem.**	3	◕	◔	◔	●	3
Pillar II: ***Support innovation***	***#PRI-6 – Create a data history*** The quality of the Copernicus data is well regarded but some stakeholders do not use it because of a lack of history, which prevents from developing precise models. **Creating a data history with compatible and comparable data coming from past contributing missions would be a growth lever while the Sentinel time series is being built.**	3	◔	◔	◔	●	3

Main recommendations expressed by Copernicus end users (sample=14)

	Stakeholders review		***PwC – Strategy& Analysis***				
Strategic pillar	***Transverse recommendations for policy action***	***Recurrence among users***	***Feasibility***	***Financial Affordability***	***Quickness***	***Strategic Impact***	***Overall priority level***
Pillar I: ***Ensure access to data***	***#END-1 – Insist on the durability of the Copernicus programme*** End users are expressing a confidence issue, wondering if the Copernicus programme will be sustained in the long term, which is an obstacle to a real economic take-off. **The EC should make a public commitment to the durability of the programme to reassure the market.**	1	◔	●	◔	●	2
Pillar II: ***Support innovation***	***#END-2 – Change the EO paradigm*** End users are not interested in the origin of the information; they just consider EO data as part of a larger ensemble. **In the current Big Data context, the EC should consider the EO market through the ICT prism.**	2	●	●	●	◕	1
Pillar III: ***Increase awareness and use***	***#END-3 – Federate new comers in the Copernicus community*** End users report a lack of understanding about their specific issues by the EO experts. **The EC could set up workshops between the Copernicus community and potential end users. An exchange platform where end users post their needs and VAS stakeholders offer their expertise could be implemented.**	3	◕	●	◕	◔	2
Pillar I: ***Ensure access to data***	***#END-4 – Propose capacity building solutions*** End users are not EO experts and they are asking for capacity building initiatives. **The EC could propose basic EO training based on MOOCs or a FAQ with a user-friendly interface where questions could be asked.**	3	●	●	●	◕	1

Introduction

Background – The Earth Observation space domain

Earth Observation (EO) pertains to the use of remote sensing technologies to monitor land, marine (seas, rivers, lakes) and atmosphere. In the EO field two broad branches can be distinguished, one leveraging airborne assets and the other based on satellites. Both families use the same sensing technologies (optical, infrared, thermal, radar, etc.).

Satellite-based EO relies on the use of satellite-mounted payloads to gather imaging data on the Earth's characteristics. The way in which information is gathered depends on the type of sensor used to capture data. EO remote sensing technologies can be split in two main families bringing different types of information:

- Passive remote sensing: the satellite's remote sensing payload monitors the energy received from Earth due to Sun energy reflected (e.g. colour of the ocean) or re-emitted by Earth surface or atmosphere (e.g. thermal radiation). Optical or thermal sensors are commonly used passive sensors;
- Active remote sensing: the satellite is sending energy to Earth and monitoring the energy received back by Earth surface or atmosphere. This type of technology enables day and night monitoring during all-weather conditions but it leads to a higher consumption of battery power. Radar and lasers are commonly used active sensors.

The maturity of the EO market varies throughout the world and highly depends on the economic and technological development. North America is by far the most developed market, followed by Europe and Australia. However, this trend is likely to evolve rapidly due to the many technological developments, which will attract many new players in the market and increase competition. The European Union is currently developing an independent Earth Observation capacity through its Copernicus programme. This programme is a cornerstone of the European Union space strategy.

The Copernicus Programme

The Copernicus programme is the European Union's Earth Observation flagship programme. From 2014 to 2020, the European Union (EU) will commit over EUR 12 billion[1], of which more than EUR 4 billion is dedicated to Copernicus, previously known as the Global Monitoring for Environment System programme (GMES).

It consists of a complex set of components that collect data from various sources: EO satellites (the Sentinels) and a multitude of in situ sensors (meaning on site or local) on the ground, at sea, or in the air. In the end, the Copernicus programme will be made up of 6 satellite categories, each of them with specific technical capabilities.

Copernicus responds to the needs of its users – European citizens – in their daily lives through its six thematic services (Land, Marine, Atmosphere, Climate, Emergency and Security) supporting the development of many applications, thus contributing to the "excellence of European industry in space". Its objective is twofold: develop an independent EO capacity to deliver services in the environmental and security fields and create business opportunities for European companies to enhance innovation and employment in Europe. The Copernicus programme should result in the creation of approximately 48,000 jobs over the period 2015-2030[2].

The European Delegated Act on Copernicus gives users free, full and open access to EO data: Copernicus services process and analyse the data, integrate it with other sources and validate the results. Copernicus is the 3rd largest data provider in the world, with 8 Petabytes per year. No previous EO initiative has ever provided such volume and diversity of data at such an impressive rate, which poses rising challenges to collect, reference, disseminate,

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[1] *OECD, 2014, The Space Economy at a Glance 2014. [ONLINE] Available at: http://www.oecd.org/sti/the-space-economy-at-a-glance-2014-9789264217294-en.htm.*

[2] *European Commission, 2015, Copernicus is the EU Earth Observation and Monitoring Programme. [ONLINE] Available at: http://copernicus.eu/sites/default/files/documents/Copernicus_Factsheets/Copernicus_May2015.pdf.*

process and deliver them. In the next five years for example, the Sentinel spacecraft alone will generate some 25 petabytes of EO data[3].

The exploitation of this data creates sound business. Today, a rising number of Small and Medium Enterprises (SMEs) focus on the development and sale of value added services and products based on Copernicus data with the objective of meeting specific end users' needs. These innovations contribute to the development of the downstream segment of the EO market value chain, which refers to companies offering value-added services that are developed outside the scope of the Copernicus governance[4]. A study conducted by the European Association of Remote Sensing Companies (EARSC) states that the sector comprises around 300 companies, 95 per cent of which are SMEs[5]. The global downstream market has an important growth potential and its development is of sizeable importance for the EU, as it accounts for 58 per cent of the global space economy[6].

Objective and scope of the study

This document is carried out within the assignment "Study to examine the socio-economics impacts of Copernicus in the EU". The purpose of the present report is to provide an overview of the EO downstream market and on the sectoral use of EO data, with a focus on ten downstream domains/user segments ensembles – denominated here as 'value chains' – under scrutiny for the study.

The value chain selection process was based on a step-wise approach.

The first steps in the process were, in parallel, the definition of a set of qualitative criteria for selection and ranking of the value chains and a desk research and literature review (for appropriate basic data retrieval and for the refinement of the selection/ranking criteria).

The process led to the identification of a long list of value chains, which was pruned after a few interactions with ESA: the consultation with ESA was carried out in order to ensure coordination with similarly scoped activities carried out within Copernicus at ESRIN, as well as to avoid needless duplication of efforts.

Next, a value chain ranking was conducted, by grading each value chain in accordance to the identified set of qualitative criteria.

The following general selection and ranking criteria were adopted in the process:

1. Relevance to wide EU strategic objectives
2. Current and prospective use of Copernicus data
3. Literature/data availability on the use of EO data
4. Expected/potential economic benefits derived from the use of Copernicus data
5. Expected/potential societal and wider benefits derived from the use of Copernicus data
6. Current wider mindshare

The above criteria were compounded by the following additional selection requirements as derived from the scope of the study:

a. Need to include some purely private value chains
b. Need to include one Landsat benchmark value chain
c. Need to include a EO2.0 comparative value chain

The ranking allowed singling out a list of 10 propositions, plus 7 additional propositions to serve as potential back-ups.

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[3] *Di Meglio, Alberto ; Gaillard, Melissa ; Purcell, Andrew, 2014, CERN Openlab Whitepaper on Future IT Challenges in Scientific Research. [ONLINE] Available at: http://www.zenodo.org/record/8765.*

[4] *European Commission, Business Innovation Observatory, 2016, Applications related to Earth Observation - Case study 63. [ONLINE] Available at: http://ec.europa.eu/growth/industry/innovation/business-innovation-observatory/case-studies/index_en.htm*

[5] *EARSC, 2015, European Geospatial services.*

[6] *OECD, 2014, The Space Economy at a Glance 2014. [ONLINE] Available at: http://www.oecd.org/sti/the-space-economy-at-a-glance-2014-9789264217294-en.htm.*

The application of the criteria above led to the identification of the list of candidate value chains reported in the table below.

Value chains envisaged
Landsat – *mandatory*
EO 2.0 actors – *mandatory*
Air quality management
Agriculture
Epidemics monitoring
Flood water tracking
Forestry management
Ice monitoring
Improving electricity provision
Insurance
Oil & Gas – Mining
Preventing volcanoes eruptions
Refugees crisis management
Renewable energies
Ocean monitoring
Urban monitoring

Figure 4 - List of value chains envisaged

The identified value chains were then ranked in accordance to the criteria defined above, by assessing, qualitatively, the relevance/applicability of each criterion on a scale from very low to very high, as depicted in the legend below. The two mandatory value chains (Landsat and EO 2.0) were excluded from the ranking. The two value chains with a strong private end users focus – oil & gas and insurance – were not ranked on the two non-strictly business criteria, "Relevance for wider EU strategic objectives" and "Mindshare".

The information provided above assesses the relevance of each criterion using the following legend:

○ ←——→ ●

Very low Very high

The table below shows the results of the ranking for the 10 proposed value chains:

Value chain	**Strategic importanc e for EU**	**Relevance of Copernicus data**	**Literature/ data available**	**Potential economic benefits**	**Potential societal benefits**	**Mindshar e**	**Results**
Landsat	-	-	-	-	-	-	Mandatory
EO 2.0 actors	-	-	-	-	-	-	Mandatory
Agriculture	●	●	●	◑	◑	◕	◕
Oil & Gas	-	◕	◕	●	◑	-	◕
Insurance	-	◕	◔	●	◑	-	◑
Renewable energies	●	●	◕	◑	◑	◑	◑
Forestry	◕	●	●	◔	◑	◔	◑
Ocean monitoring	◑	●	●	○	◕	◑	◑
Urban monitoring	◑	◑	◑	◑	◑	◔	◔
Air quality management	◑	◑	◑	◔	◑	◔	◔

Figure 5 - Value chain ranking

The present report thus focuses on two benchmark value chains that are Landsat and EO 2.0 actors, as well as on these eight promising value chains in which Copernicus programme output is currently used: Agriculture, Oil &

Gas, Insurance with particular focus on natural hazards, Renewables energies, Forestry, Ocean monitoring, Urban monitoring and Air quality management.

General approach of the study

The approach pursued through this study is based on desk research and stakeholder consultation.

The first round aimed at gathering relevant information related to the three main pillars of the report: the EO market characterisation, the sectoral use of EO data and the socio-economic assessment of the Copernicus programme through targeted desk research. The types of documents used are very diverse such as EO and sectoral market reports, conference & workshop proceedings, journals & newspapers, technical notes and policy papers. More specifically, this round relied on hunting, gathering and classifying the relevant secondary documentations available following three stages:

- The literature review on the socio-economic impacts methodologies focused on different methodologies to assess the economic and societal impacts derived from public investment in space activities. The aim of this first stage was to have a global understanding of each one of these methodologies, including their advantages and disadvantages. The context of use of each methodology was also analysed with a focus on the past studies done using these approaches. Particular attention was given to methodologies able to be directly used or adapted to assess accurately EO downstream benefits.
- The literature review focused on the EO downstream market characterisation with the objective to understand the framework and approach used to perform this type of analysis. It also provided the opportunity to gather figures and descriptive information on the EO downstream market before stakeholder engagement. Specific attention was given to documents focusing on Europe and Copernicus/Formerly GMES, but documents on the North American and African EO markets were also analysed.
- The literature review focusing on the sectoral use of EO data was the last part of the literature review. The aim of this stage was to understand how a given sectoral domain works and how the use of EO data brings value to the end users. Another goal was to understand where and how Copernicus is already used and/or can be potentially used in the future in both public and private end user value chains.

The second round relied on stakeholder consultation. This round aimed at verifying and complementing the descriptive information and the figures found in the first round of desk research. More than 280 experts have been contacted to participate. Among them, 142 experts part of 94 different entities accepted to engage in an interview during the first semester of 2016, as detailed in the figure below.

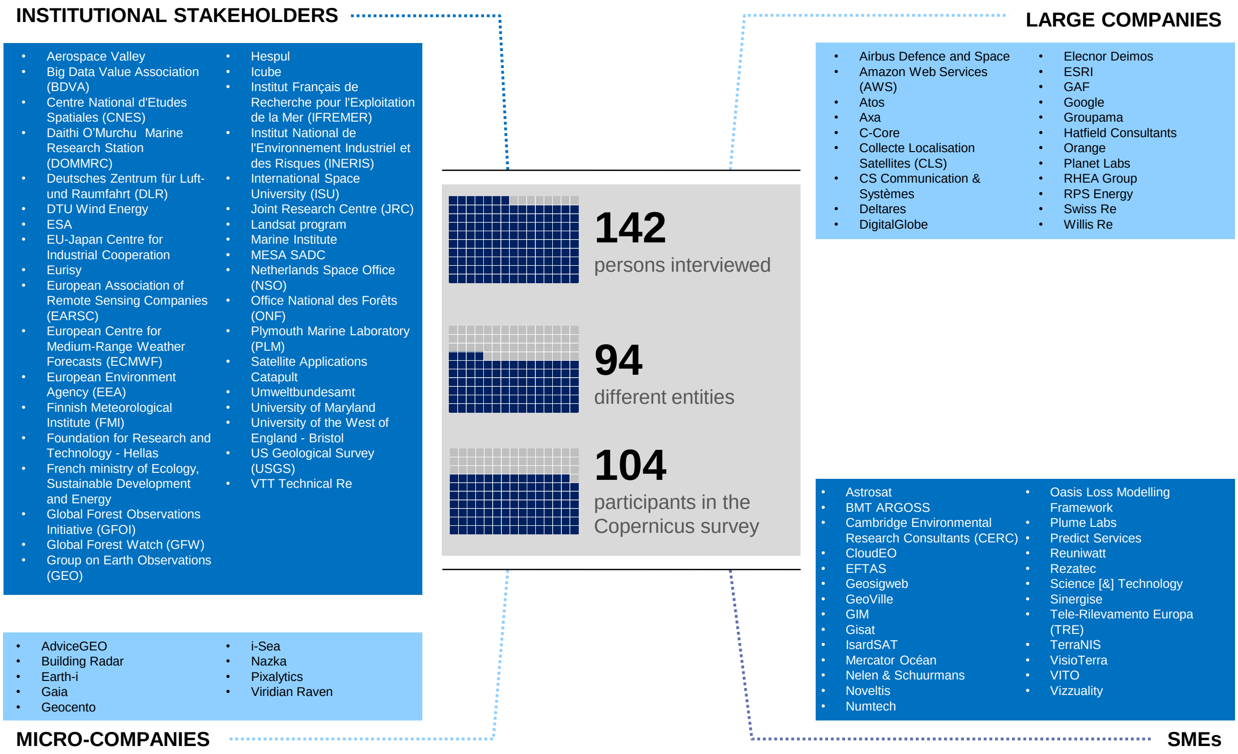

Figure 6 - List of stakeholders interviewed within this study

Content of the study

In its first part (Part A), this study displays major theoretical predictions and describes socio-economic impact assessment methodologies available in the literature, in particular methodologies to estimate enabled revenues, as well as societal and wider impacts.

The second part of the report (Part B) provides an assessment of the Earth Observation downstream market. EO downstream value chain is analysed step by step. Main figures structuring this market are highlighted. Competitive dynamics and new trends impacting the EO downstream market are depicted, in particular vertical integration, EO 2.0 actors, open data EO programmes, Unmanned Aircraft Systems, and the Geographic Information System (GIS) market.

In a third part (Part C), a deep dive into data access and dissemination is proposed. This part puts in perspective the data access and dissemination infrastructure in the EO downstream market and in the two largest open EO data programmes in the world, the Landsat and Copernicus programme.

The fourth part of this study (Part D) provides an analysis of Copernicus-enabled opportunities and socio-economic impacts on selected sectoral value chains, namely Agriculture, Forestry, Urban monitoring, Insurance, Ocean monitoring, Oil & Gas, Renewable energies and Air quality management. For each value chain, an overview of the industry is first provided. The value chain is then characterized from an EO data usage standpoint, highlighting main market trends, and detailing data flow along the value chain. The current and expected role of Copernicus within each value chain are also analysed, and its socio-economic impacts are assessed. A case study is showcasing Copernicus impacts based on a specific success story for each value chain. The strengths, weaknesses, opportunities and threats with regard to the use of Copernicus are reflected in a SWOT table at the end of each value chain. To finish with, policy recommendations are proposed to foster market uptake in each sector.

The fifth and last part of this report (Part E) gives an overall assessment of the Copernicus downstream sector and end users, by analysing Copernicus competitiveness positioning as a whole. Transverse barriers to market uptake and recommendations for policy actions are provided at the end of this study. These recommendations are not specific to peculiar value chains and apply to the Copernicus programme more globally.

Part (a) - Theoretical predictions and review of literature

From public good to public service, a discussion on public intervention

A public good is a non-rivalrous and non-excludable good and *de facto* responding to a market failure (Olson, 1967)[7]. Non-rivalrous means the consumption of the good by anyone does not reduce the quantity available for others. Non-excludable means that no one can be prevented to consume the good once it has been produced (Plattard, 2014)[8]. Following these two definitions a public good has to be provided by a State/public organisation if it is produced (i.e. air is a public good, without being produced by a given State). At the opposite, private goods are sold using the mechanism of price, *de facto* excluding consumers that cannot afford the price fixed by the market (Mc Nutt, 1999)[9]. Figure 7 gives an illustration of the four main types of products in economy.

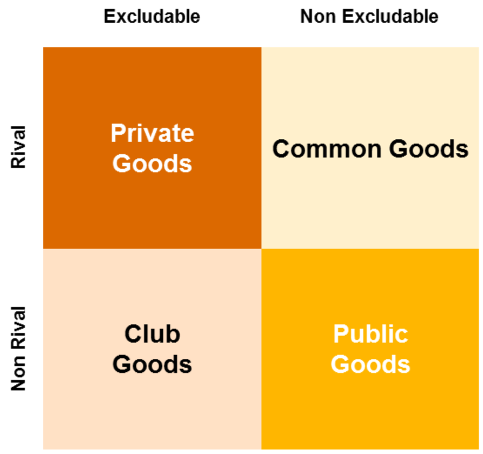

Figure 7 - Definition matrix of the different type of economic goods

The Copernicus data is definitely non-rivalrous since ESA is keeping a repository of all Copernicus data and the downloading of a Copernicus data by an actor A does not prevent actor B to download exactly the same data. The complex question is coming from the second part: can we consider Copernicus as a non-excludable good? The Copernicus programme indeed provides free and open Sentinels data. However, there are barriers to entry since there is a cost of access to Copernicus data. The actors need to acquire the equipment to read and download the data and in some cases even paying for the processing since the raw data does not bring such value to end users. Finally, an Internet connection is required to access to the data and there is no global public connection which means that it is a private cost the user has to bear. All these costs, even if they are very low in today's modern economy and will be reduced through time, can bring some issues to consider Copernicus data as a non-excludable good. **Copernicus is non-rivalrous but excludable, so it is falling into the "club goods" category**. As stated by Coase (1974), goods and services can be provided in a modern economy using other mechanisms than market.[10] A club good is a public good that becomes excludable, for example through a membership fee

[7] *Olson, M., 1967. The Logic of Collective Action. Public Goods and the Theory of Groups. Harvard Economic Studies, Cambridge, USA.*

[8] *Plattard, S., 2014. GNSS Open Signals: A de facto Global Public Good With Governance Issues. Paper presented at ICG-9, Czech Republic, Prague. November, 2014.*

[9] *McNutt, P., 1999. Public Goods and Club Goods. Department of Political Science. University of Dublin.*

[10] *Coase, R.H., 1974. The Lighthouse in Economics. Journal of Law and Economics. Vol. 23, p. 357-376.*

(McNutt, 1996)[11], such as theatre performances or untelevised sports events. Every additional member reduces the average cost of the good (economy of scale) but also brings the risk of crowding that introduces rivalry in the long term. If the cost of adding an additional member has a marginal cost of zero, the price should also be zero.[9]

A club good being non-rival but excludable, it can bring market failures. A **market failure** is an economic concept which refers to an inefficient allocation of resources in a free market. This is mainly due to the "*inability of citizens to act cooperatively and it is this lack of cooperation which mandates an allocative role for government in the economy*" (McNutt, 1996).[9] In this context, a club good has to be provided as a public service. A **public service** is a service provided by a State or a public organisation substituting for a market failure. Market failure can be due to several reasons, such as negative externalities, incomplete and missing market or monopoly. In the case of a market failure, economy needs the intervention of the government to correct such inefficient allocation of resources through tax on negative externalities, subsidy on positive externalities or laws and regulations (Ledyard, 2008)[12]. Another way to tackle market failure is through the development of a well-designed **industrial policy**. The aim of an industrial policy is to maximize economic growth, minimizing the risks of waste and rent seekers. In that sense, when a market has a malfunction, the government should intervene through an industrial policy enabling an equilibrium between interfering too much – a state leads to waste and rent seekers risks – and interfering too little – a state leads to net loss for the economy and the society (Rodrik, 2004)[13].

Every country needs a specific diversification in order to develop a competitive advantage compared to other countries. The goal of an efficient industrial policy is to perform this diversification; it relies on information and coordination externalities. The diversity of an economy's cost structure involves what is called a **self-discovery**. This discovery is not about developing a new product or a new technology, but it is about discovering well-established goods worldwide that can be produced locally at lower cost or more efficiently (Rodrik, 2004). This cost of discovery usually has to be performed by the entrepreneur (private) but even if the activity brings a great social value, it does not bring many for the entrepreneur (Hausman & Rodrik, 2003)[14]. Indeed, it is a very risky activity because if the entrepreneur fails, he bears the full cost of failure. If the entrepreneur is successful, he will then have to share the value of the discovery with the followers. In this context, the entrepreneur engaged in self-discovery activity needs "a carrot" provided by the government through trade protection, subsidy or venture capital (Hausman & Rodrik, 2003)[14]. Coordination externalities rely on the fact that government should be able to provide guarantees to organisations which are willing to invest or to assume the risk of self-discovery through ex-ante subsidies or protection in case of failures. If the projects succeed, no cash transfer or subsidies from the government need to be paid. If someone wants to invest in a new opportunity enabled by the self-discovery activity, the infrastructure has to be already developed to support the creation of a market. However, governmental intervention should be targeted on activities rather than on particular sectors and these supported activities have to be new for the economy, not the ones already established locally.

Citizens face many complex societal and environmental challenges and the government is mandated to use part of the taxes paid by citizens to monitor and manage them. EO plays a major role to solve 21st century main challenges, such as climate change, natural and technological disasters or water management. A programme like Copernicus freely provides scientific and academics communities with a gold mine of information to face such challenges, thus automatically contributing to an increase of European citizens' welfare. The research communities have generally very low willingness-to-pay and the provision of Copernicus data as private goods would have excluded a large part of these actors. A well-established private market already exists for the high and very-resolution of imagery and the provision of Copernicus data (medium spatial resolution) does not harm the European private EO market. The main costs related to the Copernicus programme are the fix cost of the infrastructure (satellite and ground infrastructures) and the maintenance and operation of the programme (e.g. satellite operations, data storage, data access, etc.). Then, the marginal cost of any additional Copernicus user is zero. As a consequence, public service enables the provision of a club good for public end user but also private. First, European private companies, from the VAS to any company of any size, pay taxes, which legitimates the fact that they can capitalize on a free access of Copernicus data without any commercial restriction. A club good such as Copernicus enables the creation of extensive positive economic externalities for the private sector that can access to free medium resolution EO data. The competitive advantage of the European EO industry and industries using EO data is stimulated by the availability of free Copernicus data and products, leading to an increase in

[11] *McNutt, P., 1996. The Economics of Public Choice. Cheltenham, Edward Elgar.*
[12] *Ledyard, J.O., 2008. The New Palgrave Dictionary of Economics. Second edition.*
[13] *Rodrik D., 2004. Industrial Policy for the twenty-first century. Prepared for United Nations Industrial Development Organization (UNIDO). Harvard University. Cambridge, USA.*
[14] *Hausmann, R. and Rodrik, D., 2003. Economic Development as a Self-Discovery. Journal of Development Economics. Vol. 72.*

current revenues and potential new streams of revenues. As a consequence, Copernicus should create new enabled revenues for the European economy, together with wider societal benefits for the European society.

The report on the Copernicus downstream sector and users benefits "Study to examine the socio-economic impact of Copernicus in the EU" was developed for this purpose. The aim of the report is to assess current and forecasted socio-economic impacts enabled by the Copernicus programme in Europe looking at different sectoral use of Copernicus data and products targeting intermediate users and both public and private end users. Several families of methodology exist to assess socio-economic impact derived from space activities, next section presents a summary of the different approaches existing and the ones that best suit the assessment of EO data socio-economic impact.

State of the existing literature on the methodologies used to assess space activities and EO infrastructure

A wide literature exists on the assessment of public investment in space activities. These economic studies have started with the need of justification of US tremendous investments in the Apollo Programme early 70 (Lowman, 1975)'[15] and they are nowadays even more important than before because of transparency requirements and high pressure on public budget. A wide range of methodological approaches were developed or adapted from the economic field to be suitable to assess the socio-economic impact of space activities. The first section introduces quickly the different families of economic methodologies used to assess the socio-economic impact of space activities. The second section focuses on the methodologies that have been used in previous studies focusing on the socio-economic impact of EO-based activities. The third section proposes a methodology to be used in the current study. Finally, the fourth section focuses on the theoretical predictions coming from past studies based on the expected socio-economic impact of the GMES/Copernicus

Literature review for socio-economic impact assessment methodologies

A literature review was performed to better understand the different approaches available to assess the socio-economic impact derived from space activities. The literature review led to the identification of seven families of economic approaches:

- Financial analysis
- Input-Output (IO) analysis
- Cost Benefit Analysis (CBA) / Social Cost Benefit Analysis (SCBA)
- Micro-diffusion models
- Econometrics models
- Multi-Criteria Analysis (MCA)
- Success-stories

All these approaches have been designed to assess specific types of economic and/or societal benefits derived from investments in a given field. The table below summarises the results of the literature review led on the different approaches used to assess the socio-economic impact of space activities.

	Advantages	Disadvantages
Financial Analysis	• Standard approach : clear and accurate results	• Lack of depth of analysis : only account for financial effects

[15] *Lowman, P.D., 1975. The Apollo Program : Was it worth it. NASA, Washington DC, USA.*

	• Comparable results over programmes, industries and time • Simple analysis	• Not able to assess effects for a multitude of actors • Specific financial data on the space sector are required but does not exist at the industry level
Input-output (IO) analysis (macro-economic approach)	• Approach commonly used in the space sector : robust methodology, commonly accepted among policy-makers and economists • Approach straightforward : clear, accurate and visual results • Comparable results, over programmes, industries and time • Very efficient to assess transactional economic impact of public investment in space (direct, indirect and induced GDP and employment impacts)	• Not enough accurate to assess precisely catalytic impacts • Not able to assess environmental and societal impacts • Need a matrix made with a large amount of industrial statistics, such as E3ME model
Cost Benefit Analysis (CBA) and Social Cost Benefit Analysis (SCBA)	• Approach commonly used in the space sector : robust methodology, commonly accepted among policy-makers and economists • Calculations robust and accurate when a market exists • Estimation of « willingness-to-pay » enables the quantification of non-monetary effects in the SCBA thanks to value of information (VOI) methodologies • Enable the accurate quantification of some societal and environmental impacts	• Calculations can become very complex when no market is available • Willingness-to-pay – derived from the VOI – is not commonly accepted among economists (SCBA) • Environmental and societal impacts involve many actors affected by the investment: the scope of analysis is usually too large (need of representative samples): definition of case studies necessary to assess all the benefits • The negative impacts, for example on the competition that does not received investment, is usually not assessed
Micro-diffusion models (micro-economic approach)	• Approach commonly used in the space sector : robust methodology, commonly accepted among policy-makers and economists • Strong methodological robustness • Able to quantify monetary and non-monetary effects • Able to quantify very complex effects, such as catalytic impacts • Accurate and precise results • Comparable results, over programmes, industries and time	• Not able to assess the transactional economic impact of public investment • Need of a robust methodology to pick the representative sample (size and type of actors, sample geographically representative… etc.) • Need many face-to-face interviews: resources and time-consuming • The negative impacts, for example on the competition that does not received investment, is usually not assessed
Econometric models by gains in outputs and productivity	• Very robust and sophisticate economic approach • Approach straightforward : clear, accurate and visual results • Comparable results, over programmes, industries and time for monetary impacts • Approach enables to create and assess a market for some non-monetary impacts (VOI approach)	• Many statistics required on the space industry • Complex calculations limit the scope of analysis, especially in the quantification of non-monetary impacts: small case study approach necessary • Results for non-monetary impacts are based on presumptions that may differ from one case to another: results for non-monetary impacts are usually not comparable
Multi-Criteria Analysis (MCA)	• Flexible approach • Very efficient to compare different investments or policies • Able to include all the stakeholders in the calculations, considering monetary and non-monetary criteria • Enable the quantification of effects when no market is available	• Not robust and accurate enough to assess alone transactional and catalytic economic impacts (complementary methodology) • Coefficients and weighting can be very subjective • Transparency risks • Need many face-to-face interviews: resources and time-consuming
« Success-stories »	• Approach widely spread, commonly	• Lack of robustness : the definition of a “success” is

	accepted among policy makers and space agencies. • Very simple, visual and inspiring results • Powerful communication tools • Able to be addressed to a larger audience than the other methodologies	very subjective • Lack of depth of analysis : use only simple data easily understandable by a wide audience • Do not quantify fairly impacts, it is an illustration of a success supported by positive statistics • Only take in account positive effects

Table 1: Relevance of each one of the six methodological families mapped[16]

The second step of the literature review was to identify the most suitable methodologies for the assessment of the Copernicus downstream industry. The downstream industry gathers all the organisations providing data processing services, software development and all other economic activities enabled by EO data, such as the use of EO data by the end users. The quantification of the processing industry and application/software developer benefits can be tackled by assessing the transactional economic impacts of such actors using Input-Output matrix. However, the quantification of user-enabled revenues is much less straightforward. Most of the studies carried out to assess the economic benefits derived from the use of EO data were performed using CBA and SCBA. Other economic approaches were used in the past, such as financial analysis, econometrics models and input-output matrix, but the results were not robust and reliable[17].

The main issue with the assessment of the use of EO data by end users is that it is very hard to track the direct paternity of the initial investment in the infrastructure (satellites, ground stations, IT infrastructure, etc.). In this context, many methodologies are not reliable. The use of CBA and SCBA enables to tackle partially the problem, listing all the benefits and all the costs associated with the infrastructure and the provision of EO data to the end users. The main issue with these approaches is that in most cases the studies are taking all the end users' benefits and revenues as a logical output coming from the initial investment or used proxy figures (i.e. 1 or 3 % of the overall benefits). This type of approach does not enable to isolate accurately the paternity of investment. However, micro diffusion models can tackle this issue. The use of micro-economic approach, using the firm as the unit of analysis, provides an interesting way to assess paternity for spin-off of space technologies and knowledge. Even if this type of approach is resource-intensive – many direct consultations are required to understand how space activities impact the current and new streams of revenues of the firm – the micro-diffusion models, especially the BETA methodology, are very accurate to provide robust and conservative minimal paternity of investment. The BETA methodology is in this case commonly accepted among economists and space agencies as a very robust methodology to assess spin-off. More details about the BETA methodology are available in the third section of the Theoretical Predictions chapter.

The next section focuses on the literature review based on the socio-economic impact assessment derived from the use of EO data.

State of the literature review focusing on the socio-economic impact assessment derived from the usage of EO data

Surveys of the EO downstream industry

[16] *This table is based on all the literature read on socio-economic studies.*

[17] *Hof, B., Koopmans, C., Lieshout, R. and Wokke, F., 2012. Design of a Methodology to Evaluate the Direct and Indirect Economic and Social Benefits of Public Investments in Space. Report commissioned by ESA. SEO Economish Onderzoek.*
Simmonds, P., Clark, J., Knee, P., Stermsek, M., Horvath, A. and Javorka, Z., 2012. Design of a Methodology to Evaluate the Direct and Indirect Economic and Social Benefits of Public Investments in Space. Report commissioned by ESA. Technopolis Group.

The first type of study is recurrent in the literature. These types of studies are the survey of national downstream industry or publicly-owned EO programme. Most of them use a financial analysis approach – please refers to next section for more details about financial analysis – and look only at the intermediate uses benefits. The following paragraphs gives thee example of survey of EO data usage, including the one performed by the USGS for the Landsat programme.

The Canadian Space Agency (CSA) is publishing every year its State of the Canadian space industry where the CSA surveys the whole Canadian industry in order to provide a financial statement on the current situation of their space industry. This annual report does not specifically focus on EO but since EO is one of key capability of Canada, notably thanks to Radarsat, Radarsat 2 and the new Radarsat Constellation (to be launched in 2018), the survey has a large component based on EO. However, there is no open data policy on any of the Radarsat spacecraft so **the report focuses only on private EO data sales and value-added services; CSA's survey only looks at the Canadian intermediate users and the figures do not include any end-users' benefits**.

The European Association of Remote Sensing Companies (EARSC) is developing a survey of the industry every 2 – 3 years using a financial analysis approach (EARSC, 2013; 2015). These reports offer very interesting information and accurate figures about the state of the EO downstream industry in Europe. Some indicators also focus on the Copernicus programme but no real economic assessment is done in the last version of the survey. EARSC considers the use of free data to be linked to around EUR 88 M in European data sales in 2014 but the contribution of the Sentinels-based products and/or data was not isolated. As mentioned in the document, some economic analysis should be available in the next industry survey. **These studies focus only on intermediate users' benefits and do not look at end-users' benefits (monetary and/or non-monetary)**.

The Landsat users survey is produced by the USGS to analyse how Landsat data are used in the United States and worldwide (USGS, 2013). These reports do not rely on financial analysis methodology but on statistics. In terms of comparison with the Copernicus programme, the Landsat one is specifically interesting since both programmes are based on free and open data policy. However, the scope of the Copernicus programme, as highlighted later in this study, is much larger in terms of sensors and bandwidth covered. The Landsat programme is considered as one of the US national capabilities so the programme does not have any requirement of economic assessment to demonstrate benefits in front of the US Congress.

US$/scene	US Users				International Users			
Value per Landsat scene	Establish	90% CI and LB	New/Return	90% CI and LB	Establish	90% CI and LB	New/Return	90% CI and LB
Median	182	157 - 207	49	42 – 55	171	146– 205	59	54 – 64
Mean (average)	912	829	367	341	930	842	463	425

Table 2: Median and mean values of economic benefits from Landsat imagery for established and new/returning US and internal Landsat users (Source: USGS, 2013)

The first limit is linked to the very important difference between mean and median for both type of users that shows the existence of extreme values biasing the sample. Another limit is related to the fact the value is derived from a hypothetical question to end-user on how much they will be willing-to-pay, which is different than paying the actual price (i.e. existence of substitutes). The third limit is that this type of **analysis focuses only on the intermediate users and a few very technical end-users which are able to search and download the EO data required; this type of analysis does not really focus on end-user benefits**.

Value of Information (VOI) methodologies

The socio-economic impact assessment of the benefits derived from the usage of EO data, and benefits derived from downstream applications in general, is complex. Indeed, the usage of EO data can vary extensively from one actor to another and from one context to another. In this context, micro-economic approach, using the firm as unit of analysis, is required. The VOI methodologies rely on the assessment of the value created by a given information when no market can be identified and so the price mechanism does not apply. In other words, the VOI methods are used to transform non-monetary impacts of the usage of information into economic value. In general, these impacts are assessed qualitatively because no economic value is available. The list of these types of benefits, where no market is identified, is huge regarding the Copernicus programme. Offering a better monitoring of the environment and studying climate change provide the society with very important benefits that do not have a direct economic value. However, this does not mean these benefits do not contribute extensively to increase society welfare. Booz&Co. (2011) have assessed that 40% of the overall benefits derived from the GMES programme (GMES was the former name of the Copernicus programme) are climate related.[18] VOI methodologies were developed to respond to this gap in the socio-economic impact assessment literature.

In situation of uncertainty, the Value of Information (VOI) methodologies are useful to assess the value of a choice, mainly in the EO field (Strategy&, 2015)[19]. Macauley (2006) explains well why this type of approach is useful for the socio-economic impact assessment of the use of EO data:

"Imagine the weather concerns of a farmer, a businessperson on her way to work, or a trucking company considering whether to place tarpaulins across the top of its trucks to protect their cargo. These individuals may be willing to pay for information depending on how uncertain they are about the weather, and on what is at stake in the event of bad weather. They may be willing to pay for additional information, or improved information, as long as the expected gain exceeds the cost of the information — inclusive of the cost of gathering and processing these data to render them useful in the particular circumstance." (Macauley, 2006, p. 274) [20].

VOI methods are based on the uncertainty of decision makers and their willingness to pay to access to more information. 4 factors impact the assessment of the "willingness-to-pay" of decision makers:

- The effective uncertainty of decision-makers;
- Outcomes of decision;
- Cost to access and cost to use such information;
- Cost to access substitute information (without EO data).

If several VOI methods exist, the most useful for the assessment of the benefits derived from EO data is the contingent valuation (Macauley & Laxminaryan, 2010)[21].

Contingent valuation methodology was developed to be able to give a monetary value to environmental goods (ecosystems, clean water, protected species… etc.) in order to value their modification (destruction, pollution … etc.). Nowadays, contingent valuation's scope was enlarged in order to be able to measure technological and health risks (diseases, pollution … etc.) into monetary value[22]. The methodology relies on the assessment the "willingness-to-pay" or "willingness-to-receive" having or dropping out the access to the good under estimation, in this case the access to EO-based information. In this context, willingness-to-pay assessment has to be performed in a very specific context to be accurate so the scope under scrutiny in all the studies using this approach is usually very small. The **results cannot be directly extrapolated to a wider population since the willingness-to-pay is very sensitive to the context of the assessment**. However, **this type of methodology focuses on the assessment of end-users' benefits.**

Case studies using VOI approach to quantify socio-economic revenues derived from the EO-based imagery

NASA (2013) has developed two interesting case studies on the Eyjafjallajökull volcano eruption in Iceland related to airlines traffic and one on the improvement of a Malaria early warning system. The authors use VOI methods to quantify the contribution of EO imagery to the management of these two crises. If the second case was not successful to quantify monetary impacts, the volcano eruption analysis has led to interesting results. The team has estimated the use of EO imagery to have saved between US$ 24 and US$ 72 million in delays and potential damages. On another hand, they have estimated that if EO imagery would have been used from the beginning of the eruption, the avoided loss would have been around US$ 200 million.[23] In both cases, NASA was focusing

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[18] Booz&Co., 2011. GMES Cost Benefit Analysis. P. 125.

[19] Startegy&, 2015. Study to examine the GDP impact of space activities in EU. Report prepared for the European Commission Enterprise and industry directorate general, June 2015.

[20] Macauley, Molly (2006). The value of information: Measuring the contribution of space-derived earth science data to resource management.Spcace Policy. Vol. 22, p. 274-282.

[21] Macauley, Molly and Laxminaryan, Ramanan (2010). The value of information: 'Methodological Frontiers and New Applications for Realizing Social Benefit' workshop.

[22] Milanesi, Julien (2011). Une histoire de la méthode d'évaluation contingente. Genèses. Vol. 84, No. 3, p. 6-24.

[23] NASA, 2013. Measuring Socioeconomic Impacts of Earth Observations. A Primer. NASA, August, 2013.

VOI methods are not commonly accepted among economists since calculations to obtain willingness-to-pay are not considered robust enough compared to other economic approaches. The scope of the methodology and the fact results cannot be extrapolated to a larger population make this type of approach not relevant for the current study. However, VOI methods are often mixed with Cost Benefit Analysis (CBA) in the Social Cost Benefit Analysis (SCBA). In this case, SCBA studies use a regular CBA methodology to quantify monetary benefits and the willingness-to-pay of end-users for non-monetary impacts. The CBA approach is explained more in depth in the next section.

Cost Benefit Analysis (CBA) and Social Cost Benefit Analysis (SCBA)

Several CBA and SCBA studies have been performed on weather forecasts (NOAA , 2007; Eumetsat, 2014) and on the expected benefits of the GMES/Copernicus programme (PwC, 2006; Booz&Co., 2011). These studies are the only ones to offer socio-economic impact assessment at programme level. However, no transparency is available on the way results are obtained, especially in the case of the study focusing on the GMES/Copernicus programme (PwC, 2006; Booz&Co., 2011).

CBA and SCBA methodology aims to sum all the benefits enabled by a given infrastructure and comparing them with the cost of such infrastructure. The approach is quite straightforward even if it can be sometime very complex to assess accurately the amount of benefits enabled by an infrastructure. The main difference between CBA and SCBA is based on the fact SCBA try to quantify the societal benefits into monetary terms using VOI methods, in most of the cases using the willingness-to-pay.

The costs analysis in a CBA involve fixed costs and variable costs. The fixed costs include the investment made to build the infrastructure. On the top of these fixed costs, several variable costs are related to the maintenance and the utilisation of the infrastructure. In the case of EO-based programme, satellite operation, data reception, data pre-processing, data storage and data provision are variable costs based on utilization of the infrastructure. The overall cost is equal to the sum of fixed and variable costs.

On the benefits side, the aim is to quantify all the potential monetary impacts this infrastructure has or can have on the economy. Societal benefits are also assessed qualitatively in the case of CBA and quantified using VOI methods in the case of SCBA – please refers to the previous section for more details on the VOI methods. In CBA and SCBA, all the entities impacted in somehow, directly or indirectly, by the use of EO-based imagery should be included in the benefits assessment. Track the benefits related to imagery up to the intermediate users is quite manageable. However, when it comes to end-users, quantification becomes way more complex since many end-users use partially EO data & products together with other sources of data and even sometime without knowing the fact the final products used is based on EO. In this context, identifying the exact benefits, avoiding over estimation of benefits, becomes complex especially to accurately assess the paternity of a benefit compared to the initial EO infrastructure. This issue is perfectly illustrated through the quantification dilemma related to the value of the navigation-based satellites infrastructure, such as GPS or Galileo, and the smart-phone market. The value of a smartphone is almost not linked to the technology and material use to build the device but it is linked the valorization of the usage of smart-phone functionalities and applications by the end-users – this value is called use value. A large part of the applications available on smart-phones rely heavily on the use of navigation data to enable applications to locate end-users and offering them with location-based services. In economic terms, do you consider the entire smart-phone market when you are assessing the benefits of the navigation infrastructure? The navigation chip being a very small and cheap component in a way more complex structure, the overall smart-phone market should not be taken as a whole. Also, many applications require navigation data to be used together with internet connection and other sources of data. However, without navigation data most of the applications and useful functionalities of the smart-phone are not working anymore and the use value of the smart-phone becomes almost zero. In such context, how do you assess the paternity of the original infrastructure compared to the monetary impact of the overall market enabled by the existence of this infrastructure? What is the most representative percentage of the overall benefits than can be fairly associated with the infrastructure? This quantification dilemma introduces the main limitation of the CBA and SCBA methodologies: assessing the real paternity of the benefits enabled by a given infrastructure. The quantification of benefits derived from the Copernicus data & products, especially when it comes to end-users, faces the exact same issue of paternity in the studies performed through CBA and SCBA methodologies. The quantification of an open and free data programme such as Copernicus is even more complex for a CBA/SCBA methodology since there is no transaction and no price mechanism. can support the assessment.

The literature review has highlighted the fact none of the existing methodologies were able to quantify accurately the socio-economic impact derived from the use of EO data, especially assessing the paternity of the benefits derived from the EO infrastructure. The size of the Copernicus programme is also a limit for socio-economic impact assessment since the number of end-users impacted directly and indirectly by the availability of free and open Copernicus data & products is almost impossible to assess. However, the early literature review on the different methodologies used to assess the benefits derived from space activities has stressed the fact micro-diffusion models have the capacity to assess accurately paternity of spin-offs derived from space-based technologies and knowledge providing conservative and robust economic estimate. The next section presents more in details the original BETA methodology, the more advanced micro-diffusion model used to assess spin-offs derived from public investment in space activities, and how the team proposes to adapt it to be used in the current study.

Methodologies chosen

Socio-economic impact assessments are important for public institutions since they demonstrate the broad benefits of public spending, and help provide transparency vis-à-vis stakeholders. Investments made in a given programme have different types of impact ranging from monetary to non-monetary impacts. Figure below gives an overview of the monetary and non-monetary impacts derived from a given investment in space activities.

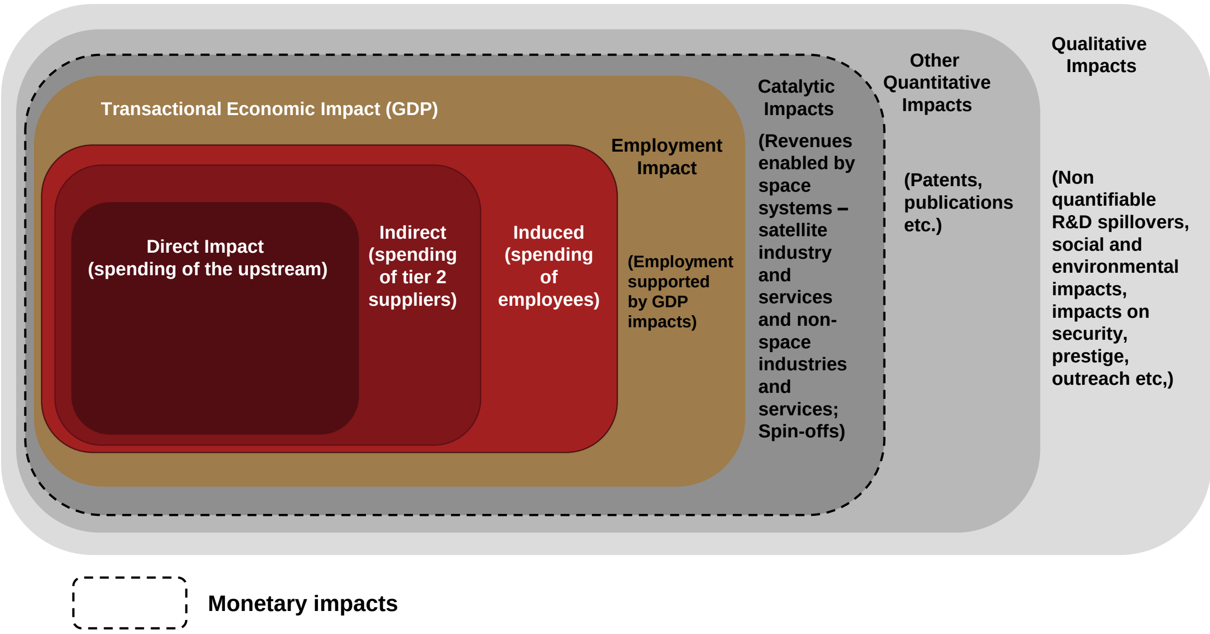

Figure 8: Socio-economic impact related to investments in a space programme (Source: Strategy&, 2015)

The transactional economic impact – or GDP impact – is the first impact to fully materialize after the initial investment. The GDP impact includes three mains economic assessment (direct, indirect and induced impacts) and an employment impact; it is one of the two main monetary economic impact, together with the catalytic impact, related to an investment in space activities. GDP impact mostly includes the impact of space manufacturing activities on the local or regional industrial sectors. The assessment of transactional economic impact is widely spread because economic impact materializes in a short-term compared to the other socio-economic impacts and various standardized methodologies exist to assess such type of impacts that facilitate comparison over time and with other industrial sectors. A previous report developed by Strategy& (2015)[24] have already assessed the GDP impact of the EC and ESA investments in the Copernicus Space segment.

Catalytic impacts are the second monetary impact materializing after investment made in space activities. In most of the cases, this type of impact requires more time to materialize compared to the GDP impact. Catalytic impact can be split in two main categories: utilization of an infrastructure funded by the initial investment under scrutiny and spin-off/spillovers effect. The first one includes all the enabled revenues by the use of a given infrastructure and this is particularly of interest in the case of the Copernicus programme. The enabled revenues of the

[24] *Source: Strategy&, 2015. Study GDP Impact. Final Report Prepared by Strategy& for the European Commission. September, 2015.*

Copernicus programme for example include all the revenues enabled by the availability of free Copernicus products, such as the sales increase of existing products or the creation of new streams of revenues. Enabled revenues by an infrastructure are mostly materializing in the downstream industry. The second one, the spin-off effect – also called spillover effect – aims at assessing the expertise and knowledge developed by an organization related to the initial investment. The knowledge and expertise developed and re-used to develop new products, new services, improvements in quality or efficiency, cost reduction, etc. are classified as spin-off effect and are quantified in terms of enabled revenues and cost reduction. Spin-off impact are mostly technological and industrial, most of these effects would appear in the upstream part of the industry; the report does not have assess spillover effect of the Copernicus upstream.

The non-monetary impacts gather the "other quantitative impacts" and the "qualitative impacts". The first category includes all the metrics that cannot be turned into economic value. The range of metrics vary from the number of patents or publications related to the programme under scrutiny to the number of life saved thank to the use of a type of satellite for example. This type of non-monetary includes all the information that can be quantified but no easily transformed into an economic value. The "qualitative impacts" gather all the non-quantifiable information such as social and environmental impact, education & science or the prestige and strategic impacts related to a given space programme.

This report focuses only on the assessment of the <u>enabled revenues</u> by the free availability of Copernicus data & products for <u>European intermediate and end users</u>.

Micro-diffusion model

Micro-diffusion models are used to understand and assess complex economic phenomenon such as knowledge and technological spin-off. The most famous and commonly accepted among economist micro-diffusion model is the BETA methodology that is used since the 80' to assess the spill-overs derived from a public investment in a given space project/grant/contract. It was used successfully for Europe, Canada and the United States of America. The team has adapted a new methodology derived from the BETA one to assess the enabled revenues by the availability of Copernicus data and products for free. Both phenomenon require a micro-economic approach The next sections present the original BETA methodology and how it was adapted to the context of the Copernicus programme.

The original BETA methodology

The economic benefits enabled by public investments in space activities are mostly intangible and complex to understand. The changing nature of spin-off requires a micro-economic approach rather than a macro-economic one in order to understand a complex phenomenon at the scale of the firm. The BETA methodology was developed by the *Bureau d'Économie Théorique Appliquée* at the *Université Louis Pasteur* in Strasbourg for this purpose. The main goal was to assess the impact of the knowledge and expertise developed by an organisation during an ESA's contract. The method was used afterward to assess the spin-off derived from Canadian Space Agency (CSA) and NASA contracts. The methodology relies on direct face-to-face interviews with executives from a large number of firms having received contracts from a national space agency. The rationale behind this micro-economic approach is to understand and capture the value-added of the expertise developed by the company being granted by a space agency, contract by contract, company per company. The use of this methodology is commonly accepted among both economists and space agencies to measure spin-off impact derived from public investments in space activities. It is a robust methodology already used several times to assess economic benefits derived from public investment in space.

The data collection is organised in a 3-step process. First, it aims understanding at the micro economic level if a company has developed a particular knowledge on a contract funded by public money. Then, if the first answer is positive, the interviewer has to understand if this particular knowledge has led to significant improvements in the company. If there are significant improvements, the next stage aims at estimating if this improvement has led to an increase in value-added capture by the firm in terms of sales increase, cost reduction and/or the retention or creation of a critical mass of experts within the company. Finally, the last step aims at estimating the paternity of the phenomenon regarding the government funding, asking for a range of percentage. On this range, the lower figure is always chosen for the analysis to provide a conservative analysis. **The aim here is to make a minimal estimation of a complex phenomenon to demonstrate its existence rather than giving an exact estimation of the economic benefits enabled by public investment, here through national space agency contract.**

The quantification method is based on the information gathered during direct interviews and secondary data such as internal documents from the companies, studies from expert groups, financial reports or official reports from national space agencies. The aim of these direct interviews is to understand and assess the effect over time of the contracts awarded to each company. These effects have to be unwitting to be considered as spillover effects and are measured by quantifying the added value associated to all investments (Guinet, 2011), estimated by the unintended sales increase and the cost reductions related to the expertise developed with each one of these contracts. On another hand, the secondary documents are necessary to better understand the context and the particularity of a given technology or product to assess properly the value-added created and the real proportion of public paternity.

The quantification method relies on the assessment of the four following sub-effects (Amesse et al., 2002) presented below:

- **Technological effect**: improvement of existing technology and/or development of a new technology due to a contract with a national space agency, leading to sales increase or cost reductions (in terms of value-added);
- **Commercial effect**: reputation effect having work for a national space agency lead to the development of an actual market or the creation of a new one, increasing sales or reducing costs (in terms of value-added);
- **Organisation effect**: improvement or development of new organisational methods, project management of quality control methods, leading to significant cost reductions (in terms of value-added)
- **Critical mass:** retention or creation of a critical mass of experts (also called Highly Qualified People (HQP)) who contribute to the competitive advantage of the firm.

The three first sub-effects are quantified through value-added at the firm level, represented by unintended sales increase and cost reduction due to the expertise developed working for a national space agency. This added-value is also expressed by the development and/or maintenance of a critical mass of experts within the firm. This highly skilled core of people contributes to the competitive advantage of the company. This sub-effect can also be quantified and expressed in terms of value-added for the company. The fourth effect is quantified separately to capture the impact of a given national space agency contract on the creation and/or retention of critical knowledge within an organisation. More details are available in the table below.

	Description of sub-effect
Technological effect	• Sales of technological products not included in the original contract with a national space agency • Sales of new products using a technology acquired or developed during a contract with a national space agency • Increased sales of current products enhanced by the experience of working with a national space agency • Sales by a new department or a new company created thanks to the technology developed working with a national space agency
Commercial effect	• Reputation effect of working with a national space agency • New network and partnerships developed thanks to the national space agency's contract • International collaborations
Organizational effect	• Quality management • Project management • Production methods
Critical mass	• Retention of a critical mass of expertise within the firm • Improvement of existing critical mass • Development of new competences

Table 3: Economic effects related to public investments in space (Source: Mosaic, 2014)

All the following quantification methodology is based on the work of Cohendet (1997).

The final unit of measurement used to express spillover effects on a firm is the added value, together with the estimated value that results from setting up and maintaining highly skilled design and production teams (defined above as the "critical mass"). The quantification exercise thus consists in determining how the work carried out by national space agency projects affects these two parameters. The process is illustrated in the diagram below. The contracts that firms obtain from the national space agency, like all their other activities, affect the four basic factors corresponding to the four types of effects described earlier (technological, commercial, organization and methods, and critical mass). These, in turn, contribute to increase the volume of sales and reduce costs, and thus, under some circumstances, contribute to increase the firm's added value.

To quantify the sales increase, the interviewees were asked to estimate, as a percentage, two sets of coefficients:

- The Q1 coefficients accounting for the estimated influence of each effect, whether technological (Q1t), commercial (Q1c) or organizational (Q1o), on the effective sales increase. These coefficients represent the proportion of economic value related to each one of the various effect; the sum of Q1t, Q1c and Q1o must therefore be equal to 100%.
- The Q2 coefficients accounting for the (minimal) estimated influence or paternity of national space agency contracts (or projects, in this case) on each one of the three effects mentioned above. These coefficients characterize how much of these effects relates or owes to national space agency investments, with regards to the firms’ other activities; while they must be between 0% and 100%, their sum is not equal to 100%. They are very often based on objective data such as the share of national space agency’s funding in the development of the product or service in question.

The increase in added value (related to sales increase) is obtained by multiplying the effective increase in sales related to national space agency activities by these two sets of coefficients.

To quantify cost reduction, the interviewees were asked to estimate savings on inputs, lower reject rates, savings in production time and miniaturization. This is calculated:

- Directly, by adding up the savings made thanks to methods acquired under national space agency contracts;
- Indirectly, by multiplying the amount of savings made over the period under scrutiny with the percentage of influence of national space agency contracts (provided by the Q2 coefficients).

The increase in added value (related to cost reduction) is obtained by multiplying the effective cost reduction related to national space agency activities by the set of Q2 coefficients, whenever required.

The total increase in added value is obtained by adding both the increase in sales and the cost reduction related to national space agency investments. This sum represents the total spillover effect or “indirect” revenues generated by the industry over the period under scrutiny in addition to the “direct” economic effects derived from national space agency investments. The “multiplier” for each company’s national space agency projects is obtained by dividing the increase in added value by the total value of the project (or sum of related contracts). The global multiplier is the average of all company multipliers, or the average value created from the spillover effect for one dollar invested in space.

This seemingly complex procedure, which remained, however, well understood by all respondents, was designed to meet two essential requirements. First, it enabled us to isolate the specific contribution made by national space agency contracts from the firm's other activities, so as to allow for the fact that technologies or production methods often stem from developments made in a number of different projects over a period of time. Secondly, it enabled us to provide a minimum estimate of the volume of spillover effects rather than a precise value attached to them (given, for instance, that some items may be overlooked). Consequently, the corporate managers taking part in the survey were asked to assess the influence of national space agency contracts in terms of an estimated range, of which only the lower figure was used for the final calculation. The focus of this study, in that respect, is more on the existence of a phenomenon, rather than on its exact quantification.

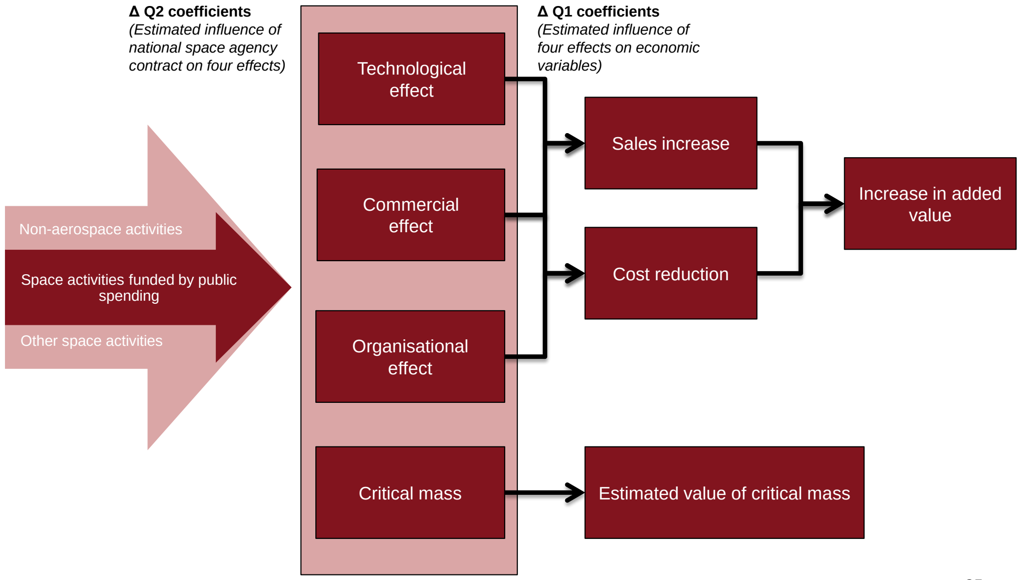

Figure 9: Quantification method of economic spillovers (inspired by Mosaic, 2014)[25]

Once the results have been obtained by type of actors on the sample under scrutiny, the results can be extrapolated from the sample to the overall population – in most of the cases the overall population is considered to be the overall contracts granted by a national space agency on a given period of time. The extrapolation is straightforward and commonly accepted among economists: once multipliers have been derived from the sample for each type of actors per type of activity, the same multipliers are applied directly to the overall population per type of activity. The overall results give a sense of a minimal estimation of the spin-off enabled by the original national space agency grants/contracts/investments.

The use of the BETA methodology is commonly accepted among both economists and space agencies to measure spin-off impact derived from public investments in space activities. It is a robust methodology already used several times to assess economic benefits derived from public investment in space; the table below summarises the existing work using this methodology.

Space agency	Topic	Authors	Publication
ESA	Assessing ESA's spin-off (European level)	Bach, L. et al.	1991
	Assessing ESA's spin-off (European level)	Bach L., Cohendet and P., Schenk	2002
	Assessing Estonia participation in ESA programmes	Invent Baltics OÜ	To be published
Danish Agency for Science, Technology and Innovation	Assessing Denmark's participation in ESA programmes	Rambol Management	2008
Fundação para a Ciência e a Tecnologia	Assessing Portugal participation in ESA programmes	Clama consulting	2011
Irish Industry	Assessing Ireland participation in ESA programme	Enterprise Ireland	2012
Norsk Romsenter (Norwegian Space Centre)	Assessing Norway participation in ESA programmes	Norsk Romsenter	2015
	Assessing Switzerland participation in	University of Applied	To be published

[25] *Source: adapted from Mosaic, 2014. Spillovers effects from CSA contracts for the period from 2005 to 2014. Report prepared for the Canadian Space Agency. Montréal, Canada.*

	ESA programmes	Sciences and Arts	
CSA	Assessing Canadian participation in ESA programmes	BETA/CETAI	1989; 1994
	Assessing Canadian participation in ESA programmes	Hickling Corp et al	1997
	Assessing CSA's spin-off (Canadian level)	Mosaic	2014
NASA	Assessing technology transfer in the space sector	George Washington University (Hertzfeld, H.)	2002
	Assessing spin-off from NASA life sciences programme	George Washington University (Hertzfeld, H.)	2002

Table 4 – Studies using an approach based on BETA methodology

The adaptation of BETA methodology to the context of the enabled revenues by the availability of Copernicus data & products

The economic phenomenon derived from the availability of Copernicus data and products for free is similar to the context of a spin-off in terms of economic quantification. As explained in the previous section, the BETA methodology aims to understand and assess the knowledge created thanks to national space contract and re-used in another context to increase sales or reduce costs. The free availability of Copernicus data and products for intermediates and end users can be assessed by understanding and assessing the type of knowledge created by these users thanks to the existence of a programme such as Copernicus. However, some calculations related to linking cost and revenues, through the provision of multipliers, cannot be performed in the case of Copernicus. The quantification of the critical mass of experts also cannot be directly performed because accessing specific information in each value chain related to the average salary of specific position/jobs within companies is too sensitive.

The methodology used to assess the enabled revenues by the Copernicus programme is a micro diffusion model adapted from the original BETA methodology to fit to the context of the use of EO data, in this particular case, the use of Copernicus data & products. **This study is the first time a micro-diffusion model inspired by BETA methodology have been used to assess the enabled revenues by the availability of free and open EO data**. The next paragraphs present the approach used to assess the enabled revenues by the availability of free Copernicus data & products for intermediate and end-users. **This methodology will only be used to assess enabled revenues when monetary benefits can be assessed for intermediate and end-users; all non-monetary impact will be assessed qualitatively.**

The **first step relies on the characterisation of the value chain under scrutiny**. The goal of this phase is to **understand the value-chain and supply-chain structure** in order to identify the scope of analysis. Using a mix of secondary documents and direct consultation with experts, the structure of each value chain is identified, **highlighting the main actors in each value chain**. Another goal of this first expert consultation is to **perform an initial market sizing** in order to understand the main components and trends on these markets (market size, growth rate, potential substitution products, relative importance of EO, etc.).

The **second step aims to identify and map the principal actors of a given value** chain in order to understand the role of each one and to gather information on each type of organisations. This step also aims to **develop a prior understanding on how EO data are used** in general, and potentially Copernicus data & products, in the value chain under scrutiny. This step should lead to the creation of a data base gathering all the relevant information per actor, such as nature & size of actor, geographic repartition, etc.

The third step is to **pick a representative sample of specific end-user for each value chain**. This step varies from the original BETA methodology since no prior data facilitating analysis are available on the population under scrutiny, such as national space agency's contracts/grants. In the case of the Copernicus programme, the team has decided to derive a specific case study within each value chain considered as representative in terms of geographic repartition and type of actors. **Each case study should include organisations from all type of actors identified in the value-chain structure (step one) and organisations coming from all over Europe.** In statistics, a sample gathering at least 30% of the observations can be considered representative if these observations chart the diversity of the overall population in terms of type of actors, geographical repartition and size of the companies. Given **the size of the value chain under scrutiny** (European O&G upstream, insurance for disaster, agriculture, renewable energies, etc.) and the **character intangible of the market for Copernicus data & products within each value chain** – the team cannot before the analysis the size of a sample representing 30% of this particular market since no prior economic assessment was performed on the enabled revenues by an open data EO programme – the **team has decided to pick the more representative case studies, without being able to respect exactly this statistical rule**; this element is one of the main limit of the methodology used.

The **fourth step is based on the actual quantification of benefits for the intermediate and end users of each value chain**. It relies on the **direct consultation** of the organisation included in the case study pinpointed during the previous step. **Two types of data have to be collected during interviews** in order to measure benefits enabled by the availability of free Copernicus data & products. **Qualitative data enables better understanding the specific context of the organisation and their business model**. Understanding how the Copernicus data & products are used (alone or coupled with other sources of data) and the importance of Copernicus data & products are useful information to support and complement the quantitative analysis, especially for the paternity assessment. **Quantification of the benefits enabled by Copernicus data is the second phase of the interview**. The aim is to assess the intermediate and end-users' benefits based on the revenues, investment made to support business development and the role play by Copernicus data to enable revenues. The quantification process **relies on the assessment of revenues increase and cost reduction, compared to the activities performed by the organisation before the availability of free Copernicus data & products**. The effects are inspired by the original BETA methodology but they were adapted to better fit the Copernicus programme context. Three types of effects have to be assessed in order to understand the impacts of Copernicus on the private end-users. These three effects can be:

- **Market effect**: the availability of open and affordable Copernicus data enables an innovative offer for the private end-users by:
  - Increasing sales of existing products;
  - Increasing sales of new products on existing markets.
  - Creating a new department/company on a new market.

- **Commercial effect**: the availability of open and affordable Copernicus data enables the development of a new or/and better commercial network for the private end-users by:
  - Developing new networks and partnerships developed thanks to Copernicus programme;
  - Developing international collaborations.

- **Organisational effect**: the availability of open and affordable Copernicus data enables organisational improvements within the organisation by:
  - Improving production methods;
  - Improving efficiency/productivity.

Once the users' benefits are assessed, a range of paternity coming from the Copernicus data & products is estimated together with the team and the organisation interviewed. In most of the cases, once the overall revenues of the company derived from the use of EO data in general is assessed; the interviewer can isolate a range of the contribution of Copernicus data & products to the overall revenues of the firm. This process is strongly related to the qualitative and quantitative data collected during all the process (context of the firm, substitution products available, etc.). On this range, the team would automatically take the smallest figure in order to provide a minimal estimation of the paternity coming from the use of Copernicus data. <u>**The aim of this micro-diffusion approach is to show the existence of the phenomenon rather than providing an exact figure to prevent overestimation of benefits**</u>. **The complexity of the economic phenomenon in the case of the use of Copernicus data & products justifies the use of a micro-diffusion model to understand at the level of the firm how the data & products are used and are creating specific knowledge leading to sales increase or cost reduction. Wider methodologies such as the GDP impact assessment methodology are not able to capture the complexity of this type of phenomenon and assess accurately such economic impact.**

The fifth and final step is to extrapolate the results obtained in the case study to the overall population. The aim of the extrapolation is to assess the overall size of the potential market for each type of actors identified in the first step of the approach. The overall market is assessed using a mix of public (Annual financial statement, industry reports and surveys, etc.) and private (Bloomberg, Technavio, Rystad Energy, etc.) sources of data. Once the market of each type of actors has been identified, the percentage of the overall revenues attributed to the Copernicus data & products per type of actors is extracted from the case study. The next phase aims to apply these percentages to the overall size of the market for each type of actors; this step enables to assess the potential size of the market for Copernicus data & products in the value chain under scrutiny.

All **the questions** asked during interviews **are semi-directive** meaning the questionnaire is a framework to access to the relevant information organised by thematic. The questionnaire is a guideline which is not based on fix questions, they **have to be adapted to the specific context of the firm under scrutiny for each direct consultation**. **The questionnaire used can be found in Appendix of this report**.

Societal and wider impacts analysis

Societal and wider impacts include all socio-economic impacts that are quantifiable but not monetary in nature. Examples are: number of publications based on a thematic associated with the publicly funded programme (knowledge creation), number of patents from companies and institutions participating to the programme, etc. Those types of impacts are especially relevant for public end users value chains where non-monetary impacts have to be assessed. Such impacts are usually assessed with a combination of desk research and stakeholder consultation. Each value chain, and so each case-study, has specific societal and wider benefits that need to be assessed. In such context, no proper methodology is perfectly suitable for this type of assessment and a mix of qualitative and quantitative approach has to be used to assess non-monetary impacts.

Societal and wider impacts include wider social benefits like increased safety and security, national prestige, environmental impacts, outreach impacts (for example, impact on university enrolment in science-related disciplines), etc. Those impacts are extremely important to assess, as they complement the view of the monetary (GDP and catalytic) impacts. It's worth noting that although there have been attempts to attribute monetary values to these sorts of impacts, the task is quite difficult due to the lack of generally-accepted methodology to achieve that.

This assessment will be carried out using a wider consultation with relevant stakeholders through: 1) an online survey; 2) phone interviews; 3) face-to-face meetings as appropriate and needed. The online survey will be carried out through a multi-layered questionnaire based on a standardised taxonomy for impacts and for the specific domains of reference. As underlined previously, the benefits analysed and the questionnaire designed will be specific to each public end users value chain under scrutiny.

Theoretical predictions related to the Copernicus programme socio-economic impact assessment

This section focuses on the theoretical predictions derived from the literature review in order to stress the expected benefits, drivers of market uptake and other hypotheses to be tested on the Copernicus programme during the study.

Socio-economic impact of the Copernicus programme

The Copernicus programme was analysed in several studies that will be used as reference to derived theoretical hypotheses to be tested during the study (PwC, 2006; Booz&Co., 2011; SpaceTec Partners, 2012; 2016). The Booz&Co. (2011) study is the most advanced study that was carried out on the GMES/Copernicus programme related to the socio-economic impact of the programme. It includes the results extracted from PwC (2006), actualizing the results and planning of activities related to the deployment of Sentinels and ground infrastructure. Both studies (PwC, 2006; Booz&Co, 2011) are the two only major studies covering all the services planned for the GMES/Copernicus programme. Such a large scope under scrutiny is of specific interest in the case of this study.

Most of the following theoretical predictions concerning the expected socio-economic impact are based on Booz&Co. (2011), complemented with some results of SpaceTec Partners (2012).

The Booz&Co. study has used a scenario approach based on four different scenarios:

- A – **Baseline Option**: *no continuity for the Sentinel Missions and no guarantee of continuity for all Contributing Missions*
- B – **Baseline Option Extended**: *extended continuity for Sentinel Missions, but no guarantee of continuity for all Contributing Missions*
- C – **Partial Continuity**: *full continuity of Sentinel Missions, with limited support for the continuity of data from Contributing Missions*
- D – **Full Continuity**: *full continuity for Sentinel Missions and enhanced support for the continuity of data from Contributing Missions*

These scenarios were developed at a point where EC & ESA have not agreed on the scope of the infrastructure and the investment related. Looking at the four scenarios, the most relevant to the current situation of the Copernicus programme seems to be the scenario D, with a full continuity for Sentinels Missions and enhanced support for the continuity of data for Contributing Missions.

The table below summarises the results of the study for the scenario D. However, no granularity and no transparency are available on the results and the calculations that have led to these results.

Cumulative, Discounted	2014 – 2020	2021 – 2030	Total
Benefits	EUR 13,2 B	EUR 28,8 B	EUR 42,2B
Costs	EUR (4,8) B	EUR (6,7) B	EUR (11,5) B
Net benefits	EUR 8,4 B	EUR 22,1 B	EUR 30,5 B

Table 5: Summary of Cost Benefits Analysis, Scenario D (programme continuity) (Booz & Co, 2011)

The interesting first result is to see the details of the expected socio-economic benefits derived from Copernicus. Indeed, if EUR 13,2 B are expected over the period 2014 – 2020 from the Copernicus programme and its six core services, revenues in 2014 and 2015 are expected to be very low, less than EUR 2,5 B (cumulative) at the European level. On this amount, most of the benefits are derived from the year 2015. This means the period 2016 – 2020 should materialize around EUR 10,7 B in socio-economic benefits all around Europe. An important limit to be stress is the assumptions made by Booz&Co. at that time because these results are based on a scenario where Sentinel Missions are fully operational as followed:

- Sentinel 1A: fully operational by the end of 2012 (launched on April, 3 2014)
- Sentinel 2A: fully operational by the end of 2013 (launched on June, 23 2015)
- Sentinel 3A: fully operational by the end of 2013 (launched on February, 16 2016)
- Sentinel 4A: fully operational at the beginning of 2018 (to be launched in 2019)
- Sentinel 5 Precursor: fully operational by the end of 2014 (to be launched in 2016)
- Sentinel 6 Jason: fully operational by the end of 2017 (to be launched in 2020)

Several Sentinels were counted as fully operational while they have been launched in 2015, 2016 or not even launched yet. In this context, the enabled benefits ex-post (2014 & 2015) should be lower than the EUR 2,5 B presented in the Booz&Co. (2011) study. Booz&Co. considers that almost none of the benefits will be related to environment over the period 2014 – 2015. They estimate these type of effects to be materialized in the long term because of a longer user uptake.

H1	The socio-economic impact of the availability of free and open Copernicus data & products is expected to be quiet low on the period 2014 – 2015. The results are expected to be lower than Booz&co (2011) estimates, around EUR 2,5 B (cumulative), since most of the Sentinels spacecraft were expected to be fully operational by 2014.

Concerning the forecasted socio-economic impacts over the period 2016 – 2020, EUR 10,7 B are expected to be materialized in Europe in all sectoral uses. The ex-ante assessment of benefits 2016 – 2020 should be quite similar, even if we can anticipate a slightly smaller overall benefits with the delayed in the Sentinel Missions (comparing current situation to the scenario D) negatively impacting Copernicus user uptake. Booz&Co also estimates the environmental benefits to be significant over the period 2016 – 2020. On the period 2014 – 2035 (scope of the Booz&Co. study), the authors estimate the environmental benefit to be responsible for around 40% of the overall cumulative benefits.

H2	The forecasted socio-economic impact of Copernicus data & products over the period 2016 – 2020 is expected to be around EUR 10 B at the European level. However, given the assumption that most Sentinels spacecraft will be operational by 2014, the overall benefits on this period are expected to be lower than initial estimates.

The period 2021- 2030 seems to offer the largest enabled revenues with EUR 28,8 B cumulative benefits. However, as already stated in the section "Methodology Chosen", to be accurate, robust and conservative a 5-year window is required to assess the forecasted socio-economic impact. The team has made the choice to focus only on the expected socio-economic benefits over the period 2016 – 2020.

The Booz&Co. study does not offer any granularity on the origin of the benefits for Europe, looking at specific sectoral use of Copernicus data & products. The others studies available on the topic do not give any insights on end-user benefits, only looking at intermediate users (SpaceTec Partners, 2012) or looking at the public policy domain only, in terms of reduction of risks and efficiency savings using macro-economic figures (PwC, 2006). Several EO market characterisation exists on end users benefiting the most from EO-based applications (eoVox; ACIL Tasman, 2010; GEONETCAB, 2013; Noort M., 2013).[26] These studies do not specifically focus on the Copernicus programme or on data derived from the same type of infrastructure in terms of spatial resolution, temporal resolution, sensors and wavelengths. However, the area highlighted to be the more promising in terms of benefits for end-users seems to be quite similar in all these studies. The main beneficiaries are expected to be the following:

- **Defence & security**: this thematic is the main customer of EO-based intelligence. However, most of the benefits are derived from very high spatial resolution and near-real time monitoring which are parameters not offered by the Copernicus programme;
- **Institutional market**: this thematic is supposed to be the largest beneficiary of a programme such as Copernicus (eoVox) as public end users. Quantifying the benefits of public end users can be very challenging since it is usually based on non-monetary benefits. Contribution to global environment protection is expected to be the main benefits derived from the Copernicus programme for such type of actors. This category includes national and European agencies, local and regional public organisations, municipalities or the scientist community (notably for environment monitoring and climate change);
- **Agriculture, fishery & forestry (living resources management):** in most of the EO market characterisation, agriculture is always presented as one of the most mature private market for EO-based applications end users; this should also be the case for the Copernicus programme. Fishery, especially monitoring illegal fishery and resource stock management, seems to be a fairly developed sectoral application based on EO imagery for both public and private end-users. Finally, forestry is always pinpointed as a large EO data & products user for public and private end users in the studies cited before. Forestry was also the topic of one the EASRC (2016)[27] case study analysing the socio-economic impacts of the Sentinels for forestry management in Sweden and stressing interesting socio-economic impact for the Swedish economy;
- **Energy & natural resources:** this thematic is another expected main beneficiary of benefits derived from EO-based applications. As the agriculture sector, EO imagery is supposed to be commonly used among private end users from identifying and monitoring resources to delivering services to household and commercial markets. This category includes the O&G industry, the Mining industry and the Renewable Energies (solar, wind… etc.) industries.
- **Transport:** the transportation industry (road, marine and air transport) is finally the last main beneficiary of EO-based intelligence, mostly for private end-users. A case study was also developed by EARSC on the use of satellite imagery by Finish ice breaker in marine transport in the Baltic sea, highlighting interesting benefits for the Finish society and economy.

[26] *Sources :*
ACIL Tasman, 2010. The economic value of earth observation from space. Prepared for the Cooperative Research Centre for Spatial Information and Geoscience Australia. Melbourne, Australia.
eoVox, 20XX. Business in Earth Observation, an overview of market development and emerging applications.
GEONETCAB, 2013. Marketing Earth Observation Products & Services. Prepared for the European Commission.
Noort M., 2013. Marketing: Earth Observation products & Services. Prepared for GEONetCab and European Commission.

[27] *Source:*
EARSC & The Green Land, 2016. What is the economic value of satellite imagery? The case of forest management in Sweden. Prepared by EARSC and The Green Land for the European Space Agency.

H3	Agriculture. Fishery, Forestry, Energy, Natural Resources and Transportation are stressed by the literature to be areas where end user benefits should be the higher related to the use of satellite-based imagery.

Drivers of Copernicus market uptake

The socio-economic impact assessment of the Copernicus programme is inherently related to Copernicus user uptake. The drivers of market & user uptake need to be identified to be able to understand and discuss the socio-economic benefits derived from the Copernicus data & products. Some proxies were used in the Booz&Co. (2011) study on Copernicus user uptake. The uptake assumptions were divided into the three categories as presented in the table below.

Category	Take-up (years)	Rationale
Immediate use	0	The outputs of the operational service have an immediate use case, and benefits begin to accrue from the start year of operations.
User uptake	1	The accrual of benefits is contingent on the uptake of services by end users (institutional and individual). The build-up period is required for promotion, dissemination and user education activities.
Policy cycle	2	The benefits arise as an outcome of inter-institutional policy-making and the trickling down of such policies through international, European, regional and local authorities.

Table 6: Copernicus take up assumptions (Booz&Co., 2011)

The Copernicus take up assumptions should also impact the ex-post (2014 – 2015) and ex-ante (2016 – 2020) benefits of Copernicus discussed earlier. Indeed, the difference between the assumptions made in the Booz&Co. study and the reality related to the launch dates of Sentinels satellites should reduce the estimate of the overall socio-economic impact of the Copernicus programme for the period 2014 – 2020.

H4	The Copernicus user uptake is expected to range between 0 (immediate users) and 2 years (local and regional institutions). The Copernicus user uptake for end user, both public and private, is expected to be 1 year.

A recent study from SpaceTec Partners (2016)[28] brings very interesting insights on the drivers of Copernicus market uptake. These drivers should be test and verify while looking at the 8 value chains under scrutiny to understand their impacts on the enabled revenues by the availability of free and open Copernicus data & products. The main drivers identified by the authors to stimulate Copernicus user uptake are the following:

- **Start-up initiatives:** *start-up initiatives should be stimulated to increase the footprint of Copernicus data & products into intermediate and end users' business models in order to create economic value for European society* (i.e. ESA BICs);
- **Events**: *the organisation of events (conference, workshops, etc.) increases awareness for a large audience about the availability of free and open Copernicus data & products*
- **Promotional activities:** *the efficient use of communications channels such social medias and websites should support Copernicus user uptake;*
- **Networks**: *the creation and the development of a network of users should stimulate user uptake. As an example, a network of Regional Contact Offices (RCOs) can bring a potentially large value-added for Europe;*
- **User feedback, training & education**: *this capacity enables the users to give feedback on the Copernicus programme and to have access to specific and dedicated training or materials related to the use of Copernicus data & products. The number of Copernicus toolkits and handbooks should be increased and publicised;*

[28] *SpaceTec Partners, 2016. Copernicus User Uptake. Engaging with public authorities, the private sector and civilian society. Report prepared for*

- **Funding instruments**: *dedicated funding mechanisms should stimulate the Copernicus user uptake. Funding initiatives based on Copernicus data & products should help to demonstrate economic proof-of-concepts of very specific applications based on Sentinels information*;
- **Data access**: *data access is a prerequisite to any successful Copernicus user uptake. The access to Copernicus data & products should be facilitated to be accessible and useful for all type of users (beginners, intermediate and experts).*
- **Contact points:** *persons in charge to respond to information requests from (potential) Copernicus users. They are also in charge to organise national or regional events and workshops. These contacts are highlighted as powerful enablers of user uptake*.

The analysis led by SpaceTec Partners has highlighted different levels of maturity in these different domains illustrated in the spider chart below.

Figure 10: Maturity level of Copernicus user uptake (European average) at national and regional level (SpaceTec Partners, 2016)

The diagram highlights European strength in "***Networks***", "***User feedback, training & education***" and "***Events***", which should have positive impacts on Copernicus user uptake at European level. As a consequence, the awareness around the availability of Copernicus data & products for intermediate and end user is expected to be already relatively high. However, the main weakness of user uptake is related to "***Data Access***" which is also stressed to be a prerequisite to any successful Copernicus user uptake. Such driver will be one of the main point of analysis of the current study to understand what is the current status and how to enhance the quality and user-friendliness of the access. This weakness should have negative impact on the overall enabled revenues derived from the Copernicus programme.

H5	Awareness around the availability of free and open Copernicus data & products is expected to be high among intermediate and end users.
H6	Data access is the main weakness of Copernicus user uptake in Europe.
H7	Data access should negatively impact the overall enabled revenues by the Copernicus programme in the value chains under scrutiny.

Theoretical hypotheses to be tested during the study

The following hypotheses derived from the literature review will be tested during the current study in order to verify them with intermediate and end users of Copernicus data & products.

H1	The socio-economic impact of the availability of free and open Copernicus data & products is expected to be quiet low on the period 2014 – 2015. The results are expected to be lower than Booz&co (2011) estimates, around EUR 2,5 B (cumulative), since most of the Sentinels spacecraft were expected to be fully operational by 2014.
H2	The forecasted socio-economic impact of Copernicus data & products over the period 2016 – 2020

	is expected to be around EUR 10 B at the European level. However, given the assumption that most Sentinels spacecraft will be operational by 2014, the overall benefits on this period are expected to be lower than initial estimates.
H3	Agriculture. Fishery, Forestry, Energy, Natural Resources and Transportation are stressed by the literature to be areas where end user benefits should be the higher related to the use of satellite-based imagery.
H4	The Copernicus user uptake is expected to range between 0 (immediate users) and 2 years (local and regional institutions). The Copernicus user uptake for end user, both public and private, is expected to be 1 year.
H5	Awareness around the availability of free and open Copernicus data & products is expected to be high among intermediate and end users.
H6	Data access is the main weakness of Copernicus user uptake in Europe.
H7	Data access should negatively impact the overall enabled revenues by the Copernicus programme in the value chains under scrutiny.

Table 7: Hypotheses to be tested during the study (PwC – Strategy& analysis)

Part (b) – Earth Observation Downstream Market Characterisation

Introduction to the Earth Observation market

The Earth Observation (EO) downstream market represents all the economic and societal impacts enabled by the information extracted from the data provided by EO-based satellites A raw datum in itself cannot be used directly as processing is required to be able to extract a specific information from it. In other terms, the EO data alone does not bring any value; it is the use of these data that derives value for it[29]. Once processed, the EO data is distributed to the end user through EO data providers. In fact, there are basically two types of end users, institutional and commercial; these are also called public and private end users. The boundary between the two user segments can be blurred very often because many actors such as EO data providers and the processing industry are, in most cases, in charge of selling imagery to both end users (public and private). The same type of imagery can also have different target end users such as flooding imagery which can be used by the insurance industry (private end user) and by the emergency response services (public end user), each bringing different types of benefits for the economy and society. **The end user benefits are not included in the EO downstream market**, even if they are in most of the cases enable by the EO downstream market.

Nowadays, the EO downstream market is per se dependent on the Geographic Information System (GIS)[30] market. GIS can be defined as a "*computer information system that can input, store, manipulate, analyse, and display geographically referenced (spatial) data to support decision making processes*".[31] GIS-based products rely heavily on EO imagery (all type of resolution) but they also include other sources of data such as UASs and in-situ data. GIS actors have strong computing power to integrate and analyse all these sources of data together in order to create high value-added products. A dedicated section focuses on the GIS market in this chapter.

The downstream market encompasses many potential sectoral domains such as the list above (non-exhaustive list):

- Agriculture;
- Transport (land, maritime, air);
- Forestry;
- Disasters monitoring (flooding, volcano, earthquakes, fires, etc.);
- Natural resource management (water resource management, oil & gas, mining, etc.);
- Renewable energy (solar, wind, hydraulic, etc.);
- Infrastructure management;
- Security and military market.

The EO downstream market relies on five main parameters that impact the type of applications and intelligence that can be derived from the raw data:

- **Spatial resolution**
- **Temporal Resolution**
- **Sensors**
- **Spectral resolution**

[29] *Maucauley M., 2006. The value of information: Measuring the contribution of space-derived earth science data to resource management. Space Policy. Vol. 22, p. 274-282.*
[30] *The GIS market can have several synonym such as Geo-spatial market, but they are all referring to the same content.*
[31] *Source: GIS Map Info website, consulted on July, 11 2016.*
Link: http://www.igismap.com/gis-geographic-information-system/

- **Archives vs. tasking activities**

The **spatial resolution** refers to the size of a pixel in the imagery. The spatial resolution impacts the accuracy of what can be seen of a given data but it is also affecting the scope of analysis, which means the size of geographic area that can be monitored in a given imagery. As a rule of thumbs, the higher the spatial resolution is, the lower the scope of analysis is.
Different categories of resolution exist but the "accepted" range can vary from one actor to another and from one sensor to another. The definitions for the tree main resolutions used in this report are the one used by EARSC for the optical sensors:

- **Low and medium resolution**: more than 10 meter per pixel;
- **High resolution:** between 2.5 and 10 meter per pixel;
- **Very-high resolution (VHR):** less than 2.5 meter per pixel. VHR imagery with higher resolution than 0.5 meter uses to have commercial restrictions – only military users can have access to such resolution – but this restriction was reduced.

The VHR type of data does not mean it is better than high resolution, each applications has its own requirements in terms of spatial resolution.

The **temporal resolution** refers to the period required by a satellite to complete an entire orbit cycle. In summary, an entire orbit circle refers to the time necessary for a satellite to take a second picture of the exact same area at the same viewing angle. The capacity to have a short revisiting time is very important for some applications to monitor in near-real time the exact same geographic area. Other parameters such as the satellite orbit and altitude are also impacting the temporal resolution.

Different **types of sensors** are available (optical, infrared, lidar, radar, etc.) depending on the payloads of the satellite. EO sensors are split in two main categories:

- **Passive remote sensing:** the satellite's remote sensing payload monitors the energy received from Earth due to Sun energy reflected (e.g. colour of the ocean) or re-emitted by Earth surface or atmosphere (e.g. thermal radiation). Optical or thermal sensors are commonly used passive sensors;
- **Active remote sensing:** the satellite is sending energy to Earth and monitoring the energy received back by Earth surface or atmosphere. This type of technology enables day and night monitoring during all-weather conditions but it leads to a higher consumption of battery power. Radar and lasers are commonly used active sensors.

The **spectral resolution** refers to the wavelength used to produce the EO imagery. Different types of wavelength band of a given sensor (radar for example) can usually be offered by the same satellite. The wavelength band choice is tied to what needs to be detected: each band is more suitable than another to monitor a specific element. For example, some wavelengths are appropriate to monitor the upper part of trees, with others it is possible to see through trees to map soils or underground materials.

The last fundamental parameter is the type of activities performed by the satellite owner, the **archives and tasking activities**. The first one relies on the automatic capture of imagery stored in public or private repositories for future analysis such as change detection activities. Tasking activities are on-demand services for actors with very specific requirements in imagery and timing, like Defence & Security users for example. The client can ask a specific geographic coverage, at a specific spatial resolution of a given sensor and at a specific time, usually in near-real time.

The EO downstream market

The overall EO downstream market in figures

EO imaging-based information products and value-added services (VAS) impact multiple downstream industries and domains, often enabling key revenue-generating applications and wider benefits. **This market includes the revenues for data sales, value-added products and information services. The <u>companies focusing on the EO downstream market are referred as intermediate users</u> (of satellites-based imagery) in this study.**

While the EO data and VAS has already been a steadily growing market over the past decade, sales are expected to rapidly expand in the coming decade, as the market takes a decisive turn in its development cycle in response to a number of concurring disruptive trends, an overview of which will be presented in the next section "Competitive Dynamics". The market for imagery, including both data sales and VAS, has grown significantly in the last years from USD 3,050 million in 2015 to USD 3,444 million in 2016, with an interesting Computed Annual Growth Rate (CAGR) of 12.79%. The market is expected to grow significantly in the coming years to reach USD 5,900 million by 2020, which represents an average CAGR of 14.11% over the period 2015-2020.

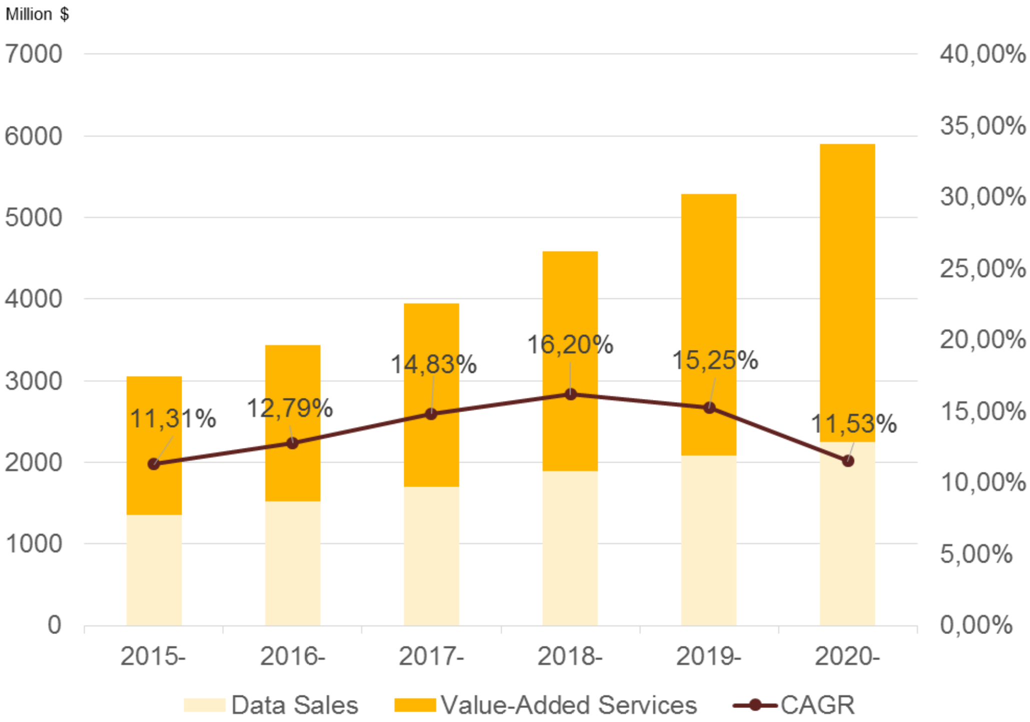

Figure 11 - Commercial data sales and VAS worldwide from 2015 to 2019 (Source: adapted from Technavio, 2015)[32]

Even if more and more private actors are entering the EO downstream market, the market is strongly consolidated with one main actor, the US-based firm Digital Globe, gathering 63% of the EO global market shares. Airbus DS Geo-Intelligence ranks 2nd with around 14% of the market, followed by Planet Labs – mostly as a result of the acquisition of Black Bridge in 2015 – with 5% and the Canadian company MDA with 2%. The remaining 16% are shared among a multitude of EO data and services providers all over the world.[33] Figure 12 summarises the world market share of the EO downstream market related to data sales.

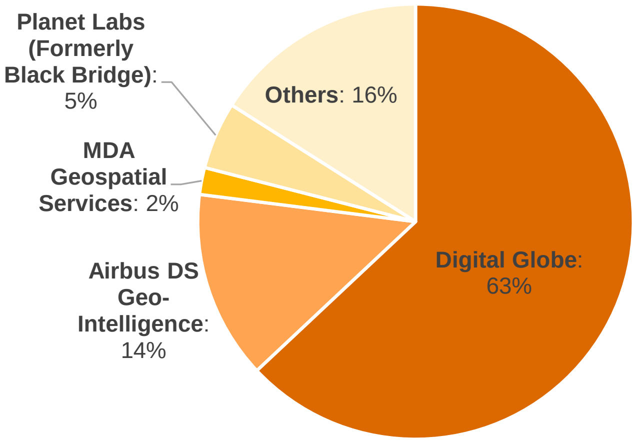

Figure 12 - World Market Share - EO data sales (Source: adapted from Frost & Sullivan, 2014)

[32] *Technavio, 2015. Global Satellite-based Earth Observation Market, 2016-2020.*

[33] *Frost & Sullivan, 2014. Global Satellite Imaging Market Insight. Detailed Global Coverage Continues to Revolutionize the Mapping Industry. June, 2014.*

The sales of EO data are mostly targeting Defence & Intelligence with 36% of overall sales worldwide in 2015. Looking at the overall EO downstream market (data sales & VAS), several verticals are of high importance ranking by order of magnitude as Weather forecast & meteorological applications (11.40%), Location Based Services (LBS) (10%), Energy (8%) and Agriculture (7%), Insurance (6%) and Mining and O&G (5.80%). The 15% remaining are split between Transports & Logistics, Disaster Management, Living Resources and Telecommunications Utilities. Figure 13 presents an overview of the main EO market verticals in 2015 and the forecast for 2020.

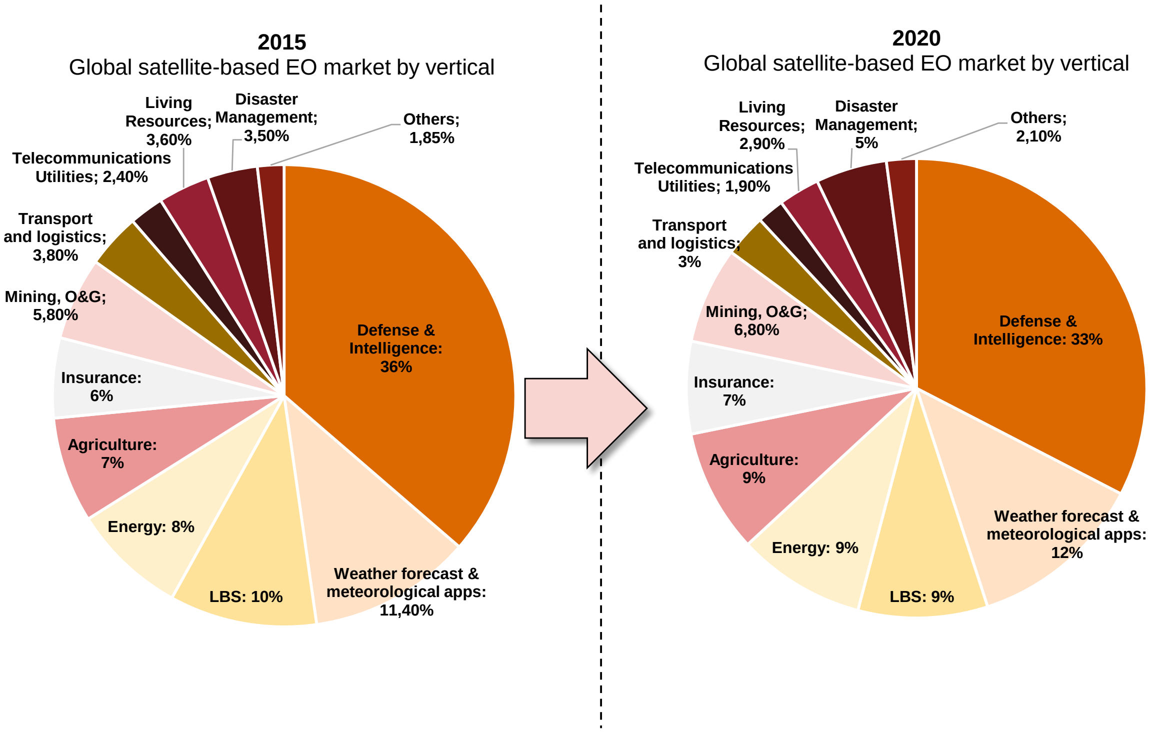

Figure 13 - Global satellite-based EO market by vertical 2015 – 2020 (Source: adapted from Technavio, 2015)[32]

The forecast for the next five years evaluates a relative reduction of 3% for the Defence & Intelligence market. A part from LBS, the main verticals are expected to slightly grow in percentage. However, the market being expected to grow from USD 3,050 million in 2015 to USD 5,900 million by 2020, the value of all the verticals is expected to increase significantly.

As shown in Figure 14, North America is the main market for the EO downstream sector, gathering around 51% of the overall market. Europe and Middle-East Africa (EMEA) ranks 2nd with 22.45% and Asia-Pacific (APAC) 3rd with 18.91%. Latin America gather less than 6% of the worldwide market.

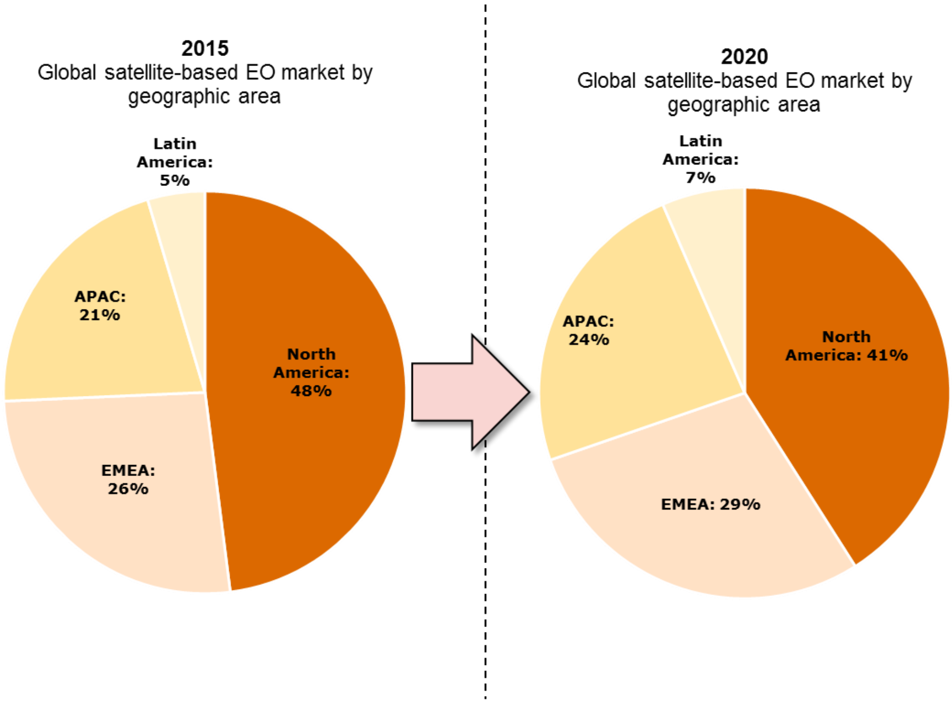

Figure 14 - Global satellite-based EO market by geographic area (2014-2019) (Source: Technavio, 2015)

By 2020, Europe & Middle-East Africa and Asia Pacific are expected to grow significantly capturing respectively 28.73% and 23.77% of the overall market whereas Latin America is expected to slightly increase from 5% to 6.52%. North America is expected to stay the largest market worldwide but losing 7% in global market shares, but keep growing in terms of value of the market.

Historically, the largest growth in EO data has been in very high resolution data and such trend is expected to continue with the increased availability of very high resolution data from both airborne (mainly UASs) and satellite systems. Increased data availability requires of course appropriate distribution models to be more efficient, secure, and capillary. Accordingly, **cloud platform holders, providing storage and easy access as well as cloud processing power and tools for basic image processing, are expected to play a major role in the EO data and products market in the coming decade.** This has already been anticipated by large companies like Amazon Web Services getting into the EO data distribution business (with an open data pilot project based on Landsat data, among other things). However, the most appropriate distribution model for real-time like data and/or video services has yet to consolidate, with a direct-to-market approach probably being preferable as opposed to one based on data brokerage.

The increased EO data supply is bound to put pressure on the pricing of medium and high resolution data, with low/medium resolution data already widely available within open data policy systems like Landsat or Copernicus. Additionally, the wider reach ensured by the new types of available data will lead, in the intermediate link of the supply side of the market, to a more and more frequent compounding of different types of data in the creation of innovative Information Products and services.

This could lead to a reduction of margins at the data supply level for traditional data sources, and, consequently, to a shortening of the EO value chain, with vertically-integrated players able to touch almost all parts of the downstream industry (and specifically the most remunerative value creation part associated to the production and sale of Information Products and VAS).

The stakeholder consultation carried out within the study suggests that new data providers/new entrants do not yet have a clear and defined go-to-market strategy for the new type of high resolution/high temporal resolution data and EO video data they produce. So far they seem only to be pushing data supply to the market and waiting for the pull of the intermediate users that receive it and put it to good use in the development of new products.

The European EO downstream market in figures

The European EO downstream industry is represented by the European Association of Remote Sensing Companies (EARSC). The association is performing every 3 years a dedicated survey on the state of the European EO downstream industry. The figures may differ a little bit from the one in the global EO downstream section based on Frost & Sullivan and Technavio figures. Following Technavio estimates, with 22.45% of the worldwide market of USD 3,050 million (2015), Europe should weight around USD 685 million. However, EARSC estimates the **European market to be EUR 911 million in 2015**, potentially due to the fact that satellite operators are involved in the EARSC survey.

The present section is based on EARSC figures only. The EUR 911 million of the European downstream market can be spilt as shown in the chart below.

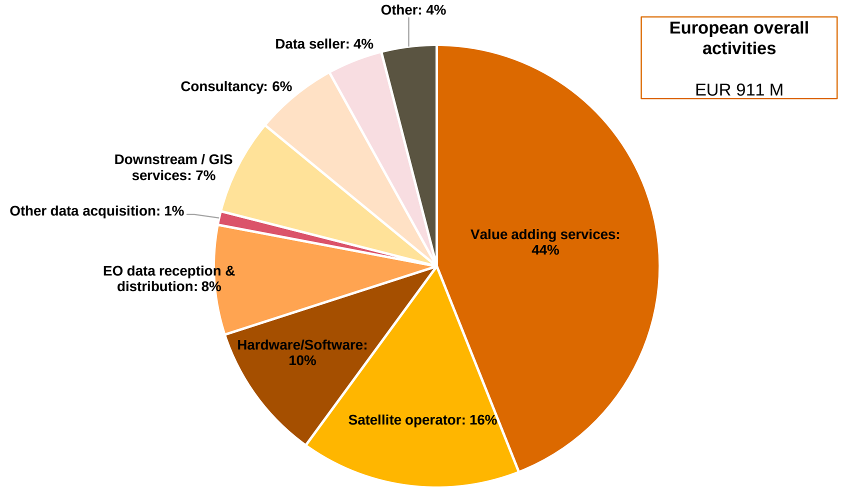

Figure 15 - Split of European downstream activities in Europe (Source: adapted from EARSC, 2015) [34]

The largest share can be attributed to the VAS activities gathering almost half of the market with 44%, followed by satellite operations/data sales activities and hardware/software providers with respectively 16% and 10% of the European EO activities. All the other activities (30%) represent for each one less than 10% of the European market which rank by order of importance: EO data reception & distribution, Downstream/GIS services, Consultancy, Data Seller and other & other data acquisition.

As highlighted in the introduction of the EO market characterisation, spatial resolutions and types of sensors are very important in the EO downstream sector. Figure 16 summarises the European/Canadian data sales per type of sensors and spatial resolution and the value perceived by the actors on the same criteria.

[34] *EARSC, 2015. A Survey into the State and Health of the European EO Services Industry. Prepared by EARSC, under assignment from ESA. September 2015.*

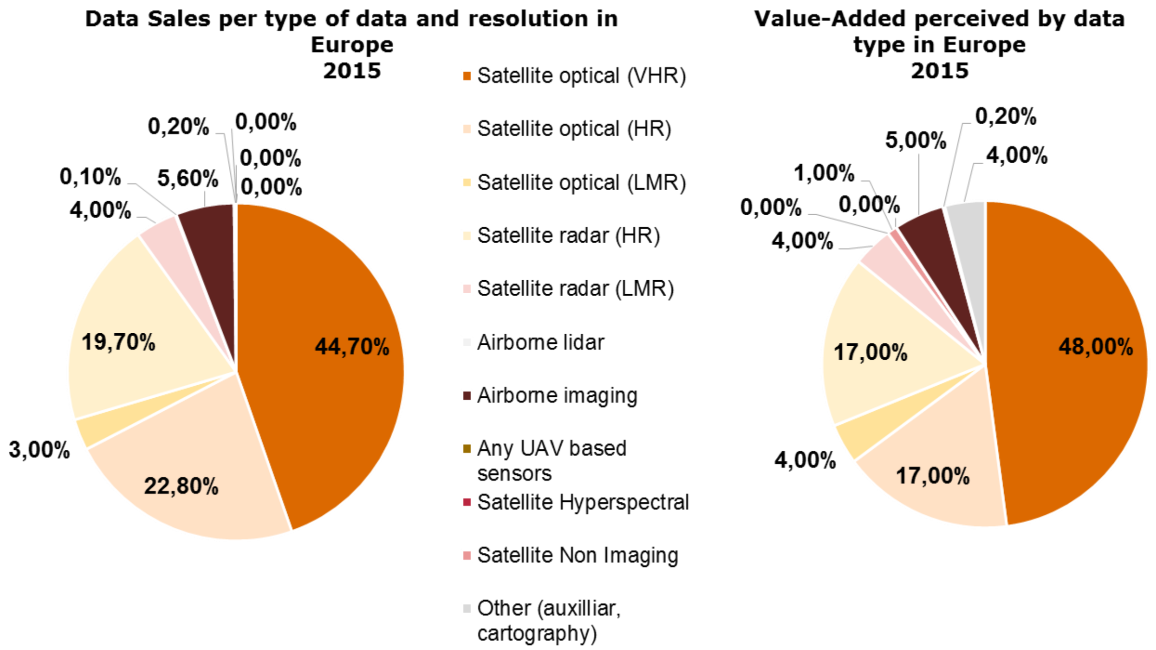

Figure 16 - Commercial data sales and data value perceived per type of resolution and sensor (Source: EARSC, 2015)[34]

VHR optical data is the main source of EO data sales, with 44.70% of the European EO data sales, and it gathers almost 50% of the sector revenues. The two other major sources of data sales and, logically, of value for the industry are HR optical data and HR radar data. All together, these three sources of data represent 87.2% of the European/Canadian data sales and 82% of the sector revenues. **Optical data accounts for around 70% of the market value, with radar representing 21% and airborne data 5%.**

All the figures presented are based on the sales of commercial EO data and so they do not include the free data obtained thanks to programmes such as Copernicus or Landsat.

It is furthermore important to highlight the significant decline of commercial revenues on medium spatial resolution (less than 10 meters) on the European and Canadian EO downstream markets, from 15% of the market in 2012 to only 3% in 2015. This important fact is mostly due to the anticipation of Sentinel-2 data now available for free, which should lead to important cost reduction in the offer of services for the EO downstream companies. **Revenues derived from open data have grown from EUR 68 million in 2012 to EUR 88 million in 2015 for Europe and Canada**.[34]

Competitive Dynamics on the EO downstream market

Vertical integration and EO 2.0 actors lead to higher competition

The EO downstream market is characterised by increasing competition with the emergence of new private actors (EO 2.0 companies[35] and other private initiatives) and new governmental actors (emerging countries investing in developing their own EO activities).

On side of the traditional actors, **EO satellites manufacturers have pursued vertical integration strategies** to capture new revenue streams on the promising EO downstream market. This approach was used by many companies such as the **Canadian manufacturer MacDonald, Dettwiler and Associates (MDA) and its Geospatial services division or the European manufacturers Airbus Defence & Space (DS) as well as Thales Alenia Space and respectively their divisions Airbus DG Geo-information and e-Geos**. Such industry consolidation strategies are similar to what was pursued a few years ago by the US company Digital Globe, world

[35] *A dedicated sector on the EO 2.0 trend is available.*

leader on the EO downstream market after the acquisition of GeoEye in 2013: the consolidation has enabled them to position themselves as the national champion on the EO downstream market and so the US reference when it comes to imagery. Airbus DS Geo (Formerly Astrium Geo) has acquired the European traditional EO downstream leaders Info Terra and SPOT Images, and other smaller companies, to pursue the same type of approach at the European level. This approach enables manufacturing companies to **diversify their risks** tackling new markets but it also enables them to **attack market with higher margin**. Indeed, manufacturing activities are very capital-intensive with low profit margin and low CAGR compared to the downstream market. This vertical integration also leads to the emergence of very large entities on a market comprised of a vast majority of micro and Small and Medium Enterprises (SMEs). Such actors vertically integrated have a **very strong purchasing power compared to SMEs** which enable them to acquire a lot of their competition, leading to a **strong consolidation on the EO downstream market** where 84% (2014) of the worldwide market is split between four companies[36], three of them being vertically integrated. However, the fourth one is the world market leader Digital Globe and they do not follow this vertical integration strategy, outsourcing the manufacturing of satellites to third parties. This is mostly due to historical reasons of this company that is the result of several mergers between former US EO downstream market leaders, leading to the creation of the EO downstream market global leader of today with 63% of worldwide market shares[36]. This last statement confirms however the trend of consolidation on the EO downstream market.

The emergence of the space start-ups on the imagery market stimulates competition on the market with their **constellations of small satellites**. A huge amount of EO data is expected to come from these commercial initiatives able to monitor Earth in near-real-time. Most of these EO 2.0 actors are targeting very high resolution imagery (mostly optical) with a very high tasking capacity compared to conventional actors[37]. These new actors are bringing down the cost of access to EO products and services and they should enable the development of mass-market for very high resolution imagery in near real-time in a near future. Traditional actors have failed to develop such commercial market because of the high cost and low capacity of their tasking activities. A dedicated case study on the EO 2.0 companies is available after the Data Distribution & Acquisition chapter.

The UAS market

Unmanned Aircraft Systems (UAS) represent a new type of data source for the imagery market. The data provided by drones are very useful for small area survey (very local applications), providing very high spatial resolution imagery. UAS data are very useful to calibrate and verify very specific area together with satellite-based imagery, especially to be used as a baseline for projects. UAS can be seen as a threat for satellite-based imagery because they provide very high resolution data for very local areas that can be used as a substitute for very high resolution satellite-based imagery. However, this source of data is complementary to medium and high resolution data for large areas and so UAS data do not constitute a threat for a programme such as Copernicus.

The UAS market is stimulated by a growing demand for very high resolution in near-real time. The cost for such type of UAS is way lower than the one currently offered by traditional EO downstream players. A drone is able to offer any user a data in a very short period of time just being flown around a given area of interest, at a lower cost than any private EO high resolution satellite. In fact, experts consider the drone market should be able to reach the size of the private satellite-based EO downstream market in the next 15 years.[38] However, the data derived from UAS are still not at the same level of quality than the one obtained through satellites. The satellites EO data are extremely precise and calibrated data obtained through professional software compared to UAS data that are obtained through customer software which are not as powerful as the satellite ones. A satellite provides very accurate, georeferenced and standardized data that are very easy to integrate into 3D mapping applications for example: you know exactly what and where is the pixel. The accuracy, robustness and standardization of UAS software are not high enough yet to provide the same quality of 3D mapping for example. UAS technologies are also still not accurate enough to be programed to monitor exactly what you want to see.

The current simplification and automatization of drones operations and data processing should stimulate the development of the UAS market, with a significant increase in the quality of the outputs (data and products). Simplifying the accessibility and the operation of drones by using simple devices (e.g. tablets or smartphones) will

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[36] *Frost & Sullivan, 2014. Global Satellite Imaging Market Insight. Detailed Global Coverage Continues to Revolutionize the Mapping Industry. June, 2014.*

[37] *Most of the traditional actors, especially the consolidated ones such as Digital Globe, Airbus Geo or e-Geos, have to offer priority tasking activities to their main clients (military and large private companies). These actors using very powerful large satellite, they do not have the capacity to offer their other clients tasking activities in near real-time at an affordable cost compared to smaller and more flexible companies.*

[38] *Source: Stakeholder consultation*

lead to the creation of high-value added for the business.[39] Other new technological advancements in the area of hardware, software and data processing should also contribute to the dissemination of UASs data at a lower cost, affecting reliability, safety and efficiency of UAS-based imagery. New types of power sources can also be expected in a near future, leading to an increased flying time for UAS.[39]

Finally, even if different drivers were identified earlier, the UAS market needs to overcome the following barriers to be able to grow efficiently, especially at the regulatory level:

- **National regulatory frameworks** are required to enable and facilitate the use of commercial UAS and the provision of certified commercial licence market. Currently, many countries do not have any UAS regulatory framework preventing the commercial use of drones, especially in developing countries where the market is expected to be very promising in energy, extractive industries or water management for example[39]
- **Insurance related to the use of drones** need to be developed and adapted to the UAS market for liability reasons in case of accident. Indeed, insurance is mandatory for aircraft users in case of physical losses (drones, equipment/instruments, ground stations, property damages or injuries to third parties). In such context, insurance is a significant risk for UAS market that needs to be taken into account[39]
- **Privacy** is the third important barrier that currently prevents the drone market to grow. A specific air control and traffic would be required to insure drones are not violating restrictive airspace, especially in airport or military areas. This privacy issue can also be raised related to confidential/sensitive data related to personal data (the definition of personal data is quite broad).[39]

However, the UAS is expected to grow significantly in the future to become as big as the satellite-based imagery market in the mid-term. Even if in the vast majority EO downstream actors are not using UAS directly, they are expecting to get in this market in a near future, when all the barriers discussed before will have been overtaken.

UAS market, even if it can be seen as a threat for some EO downstream actors, is also a potential new stream of revenues associated to the capability to complement satellite-based EO data with very local high resolution imagery, especially to access specific sensors such as LIDAR. The availability of near-real time data at low cost also enables the development of a commercial mass-market in a near future, as already stated in the discussion about EO 2.0 actors.

The GIS market and new trends related to ICT

The EO downstream market is more and more dependent on the Geographic Information System (GIS)[40] market. GIS enables the users to create dynamic relations between spatial geo-referenced data and situational/relational data based on the specific need of the users such as internal statistic or in-situ data. The combination of these types of data brings a large value-added for both public and private end-users, linking imagery to a multitude of complementary other sources of data. The figure below gives a non-exhaustive overview of the potential components of a GIS product, highlighting the major role played by imagery from all sources and resolution. On the top of the imagery data, many different types of data (in-situ, social media, commercial and public data) are aggregated thanks to powerful computing and analytics power in order to create dynamic links between imagery and very specific information to respond to very specific end-user requirement and create very high value-added unique output. The processing and the integration of all these sources of data together enable the transformation of raw and isolated data into very powerful business intelligence.

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[39] *PwC, 2016. Clarity from above. PwC global report on the commercial applications of drone technology. PwC Drone Powered Solutions. May, 2016.*

[40] *The GIS market can have several synonym such as Geo-spatial market, but they are all referring to the same content.*

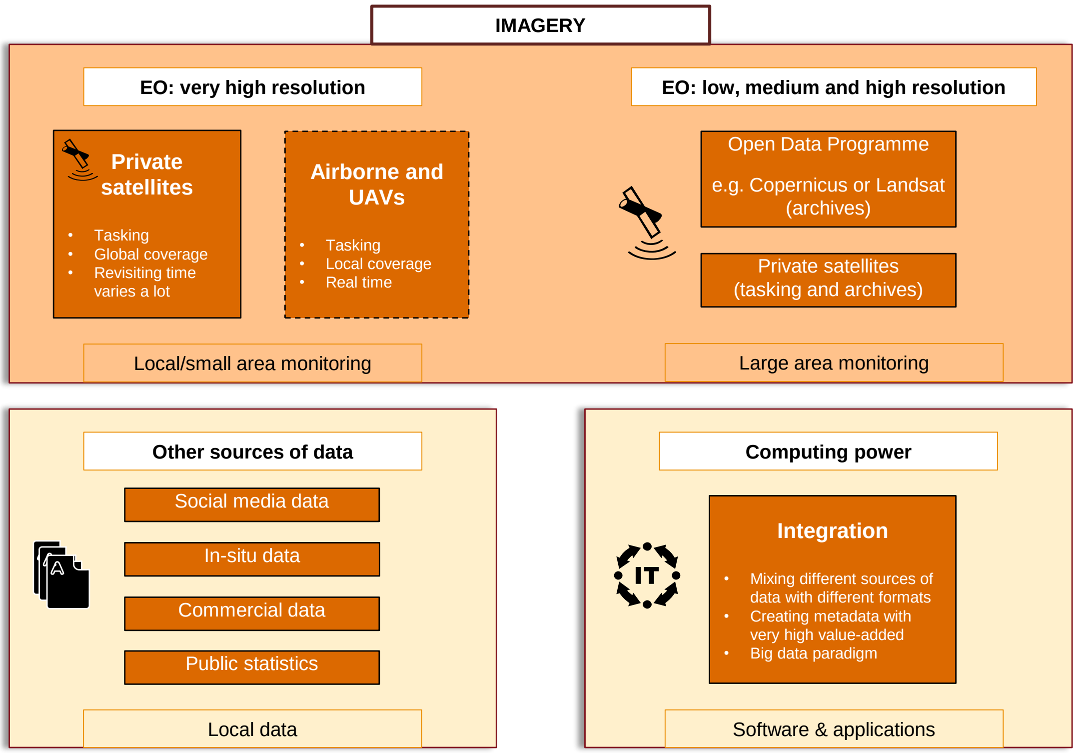

Figure 17 - Components of GIS products (Source: PwC-Strategy& analysis)

Satellite-based EO data but also airborne data (including UASs data) are at the heart of GIS products and services. GIS providers add on-the-top on this core imagery many other sources of data (in-situ data, navigation data, social media information etc.) and users can also upload their own data directly on GIS platforms. In this context, companies from the EO downstream sector have a competitive advantage in processing imagery and providing value-added products and services. Many EO downstream actors are attracted by this market, from the large vertically integrated actors such as MDA Geo-spatial, to the VAS providers such as Digital Globe or the EO 2.0 actors such as Terra Bella/Google. Most of them, at least the EO 2.0 actors and the large vertical integrated ones, even have their own capacities in data acquisition and tasking activities to respond to very specific needs of users in a short period of time, even near-real time for some actors. **The strong growth of GIS market should be seen as a positive way of growth for EO downstream actors if they manage to adapt well to such market where sources of data are multiple**. The context of Big Data should be seen as an opportunity to have access to new sources of data and new sources of computer and analytics power. Big Data and Cloud Computing are analysed in the next chapter on Data Access and Distribution.

All the figures presented here concern software, products and VAS revenues for GIS companies; any revenues related to EO data sales are included in these values. However, no figures were found on the share of the overall GIS revenues worldwide directly attributed to imagery. The figure below gives an overview, at a very high level, of the GIS value chain.

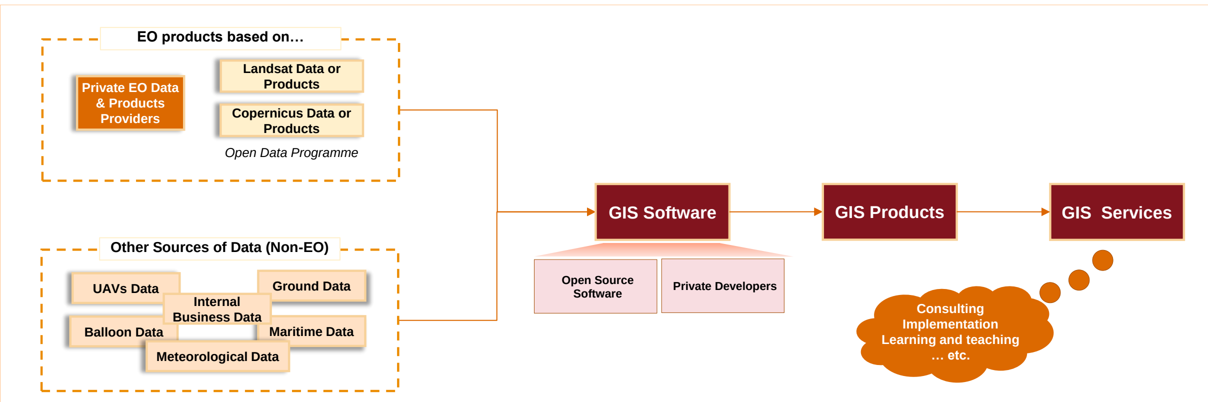

Figure 18 – GIS value chain (Source: PwC Strategy& analysis)

EO products, based on private EO data and/or open EO data coming from Landsat or Copernicus programme, are used as inputs for much larger GIS products including a large variety of other sources of data such geographic data or internal business data. The list of the sources of non-EO data presented here is not exhaustive, it can also include many other sources of data such social media data or sensors data (internet of things, etc.). The three main blocks of the GIS value chain (GIS software, GIS products and GIS services) are explained more in details in the following sections and are presented with figures for the European and worldwide GIS markets.

The overall GIS market worldwide

The global GIS market is way bigger than the EO downstream market. The **overall GIS market is estimated to be around USD 9.757 billion in 2015**. With a **forecasted CAGR of 10.35% over the period 2015-2020, the GIS market should reach USD 15.96 billion by 2020.**[41]

The overall GIS market can be split among the following end-user, by order of importance:

- Government: 16.26% (USD 1,556.89 million);
- Natural resources: 12.50% (USD 1,219.63 million);
- Utilities: 12.29% (USD 1,199.14 million);
- Military: 10.63% (USD 1,037.17 million);
- Telecommunication: 9.98% (USD 973.75 million);
- Other: 38.34% (USD 3,740.83 million).

The category "Other" includes a wide variety of end users, ranging from transportation and healthcare to real estate and construction.

In terms of geographic repartition, the overall GIS market remains mostly led by sales in developed countries, US being the largest market. Revenues are split as followed:

- Americas: 42% (USD 4,097.94 million);
- EMEA: 33% (USD 3,219.81 million);
- APAC: 25% (USD 2,439.25 million).

The global GIS market is split as shown in the figure below, software sales representing 49% of the market and Data & Services accounting for the remaining 51%.

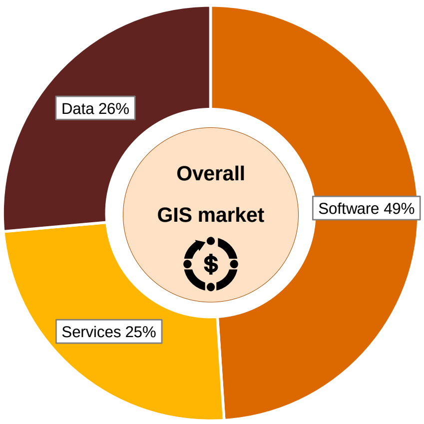

Figure 19: Overall GIS market by product segmentation (Source: Technavio, 2016)[41]

The following sub sections give more details on each segment of the overall GIS market.

The GIS software market worldwide

The GIS software market is based on the development and sales of GIS software able to process very specific data in order to create useful information for the end-users; it includes industry-specific GIS software providers for industry such as Oil & Gas for example. It is the largest GIS market and it is expected to remain the main one in

[41] *Source: Technavio, 2016. Global GIS Market.*

the coming 5 years. The GIS software market is valued at USD 4.76 billion in 2015 and expected to reach USD 7.643 billion by 2020, with an average CAGR of 9,85% over the period 2015-2020.

The GIS software market is then segmented into five main categories:

- Desktop: 52,00 % (USD 2,475.2 million)
- Server: 23,60 % (USD 1,123.36 million)
- Mobile: 10,75 % (USD 511.7 million)
- Cloud: 10,60 % (USD 504.56 million)
- Developer: 3,05 % (USD 145.18 million)

The new trends on the GIS software market are related to the context of cloud-based storage, big data and the new platform paradigm explained in the next chapter. More details are offered on these new trends in the chapter "***Data Access & Dissemination***", section "*New trends on data distribution and data access*". The market for cloud and mobile GIS are very promising for the GIS software market. Both markets have grown significantly over the last years and each of them already account for 11% of the overall GIS software market according to Technavio market researches.[41]

The cloud GIS market includes all the revenues generated by the cloud GIS software segment. Cloud GIS facilitates storage, interoperable solutions and integration of GIS solutions, enabling end-users to access in real-time maps, data storage and access and data analysis for managing assets. Cloud GIS also enables usage of GIS products in remote areas where strong internet connection is not available. However, an internet connection is required to access such type of GIS services. The market was estimated at USD 519 million in 2015 and expected to grow at USD 875.9 million by 2020, with an average CAGR of 11.03% on the period 2015-2020. The largest market for cloud GIS is North America with 47.39% of the worldwide market. The key markets for GIS cloud are natural resources (20.05%) – notably O&G –, telecommunications (16.15%), utilities (13.00%) and government (10.89%). Major actors on the cloud GIS market are Esri (world leader), Hexagon and Carto DB. [42]

The mobile GIS market includes all the revenues generated from mobile GIS systems, where the main actors on the market are again Esri (world leader) and Hexagon. Mobile GIS are defined by Technavio as solutions that "*integrate global positioning system (GPS) technology, portable hardware platforms, and GIS software. As they can access multiple layers of spatial datasets, mobile GIS solutions perform more complex analysis in the field than data collection systems*".[43] GIS mobile solutions facilitate rapid data dissemination from the location where GIS maps are built and then transferred to workers on the ground, even in remote areas, to facilitate their activities. The use of such type of GIS software enables increased in efficiency and productivity at low cost. The current market (2015) is estimated at US$ 523.9 million with North America accounting for 49.28%; the market is expected to grow to USD 845.1 million by 2020, with an average CAGR of 10.04% on the period 2015-2020. The key markets for GIS mobile are government (21.50%), military (18.25%), natural resources (17.00%) – notably O&G – and utilities (8.50%).[44]

The GIS data market worldwide

The GIS data market is based on the output created by GIS software, ranging from predictive analysis to digital maps data. The first type of data refers to all the data used internally by companies to operate more efficiently meanwhile the second one refers to digital maps based on geographic and location based information. Digital map data include in most of the cases satellite-based imagery, together with other sources of information. EO data can also be included in specific set of business data. In both cases, the imagery's contribution is almost impossible to isolate.

The overall GIS data market is valued at USD 2.578 billion in 2015 and expected to grow to USD 4.373 billion by 2020, with an average CAGR of 11.15% over the period 2015-2020. The market for GIS data is split as followed:

- Business data: 66% (USD 1,701.48 million)
- Digital mapping: 34% (USD 876.52 million)

The GIS services market worldwide

The GIS services market refers to the revenues related to the sale of specific services such as consulting, implementation, e-services or training and education. These services are built on the top of the two other GIS

[42] *Source : Technavio, 2016. Global Cloud GIS Market.*
[43] *Source: Technavio, 2016. Global Mobile GIS Market. Page 6.*
[44] *Source: Technavio, 2016. Global Mobile GIS Market.*

market, to support the delivery and the use of GIS solutions. The largest share of revenues on the GIS services market is derived from consulting and implementation.

The worldwide GIS services market is valued at USD 2.403 billion in 2015 and expected to grow at USD 3.945 billion by 2020, with an average CAGR of 10.43%.

Esri and its Arc GIS platform[45]

The US company Esri is the world leader on the GIS market. Esri is providing a digital workplace, the Arc GIS platform, where users can find multiple sources of data, from the free and open ones, such as Landsat, Copernicus or any open data available, to the fee-based ones available on the digital marketplace. Esri offers then a playground where users have access to dedicated analytics power through on-the-cloud software and toolboxes able to match and understand correlations between multitudes of data sources. The users can also upload their own data on their personal interface to be used in their GIS products. Imagery, including satellite-based EO and airborne sensors (UASs, helicopters and aircrafts), is at the heart of most of the GIS products. On the top of this imagery, many other sources of data are plugged, leading to very high value-added products in order to respond to very specific users' needs. Through Arc GIS, users have access to a continuous platform with all the data directly available on the engine and many potential software and tools freely available. For the most specific ones, the Arc GIS marketplace offers a wide range of commercial software, tools or specific sets of data to better respond to users' needs. For the new customers without experience in GIS products, Esri also offers consultancy services and trainings to teach future users on the use and the capacity of Arc GIS.

The software can be used by anyone in the organisation to develop GIS products tailored to the exact needs of the organisation, from the planning of activities, to the logistics and the marketing team. Once the products have been designed, they can be shared via specific applications on laptop or mobile (smartphones, tablets, etc.) to be used on the ground and in remote areas, without the need of a powerful internet connection.

What is the business model?
Users are paying a fee-based access with a price dependent on the number of users within the company and the usage of data (volume of data). For instance, an organisation using large volume of data on–the-cloud will have to pay more since the cost of storage will be higher for Esri. The company also sells extensions of the Arc GIS platform improving capacities of the software or customizing it for specific usage, such as Defence. Esri is finally making revenues through the Arc GIS market place where specific software, toolboxes and data sets are sold.

How are the data stored by Esri?
The user has the option to store all its data on the-cloud or it can be stored on its own servers – some actors require this type of storage for security reasons – and being linked to the Arc GIS platform. The on-the-cloud storage is divided between Amazon Web Services and Microsoft Azure, data being stored in Europe and in the US.

Some figures about Esri and Arc GIS
Esri, with more than 2.2 million users all over the world and more than 900,000 in Europe, is the precursor and leader on the cloud-GIS and mobile-GIS markets. Worldwide, more than 350,000 organisations are using Arc GIS in 48 countries. Users range from public authorities, such as government agencies, municipalities, cities and defence organisations, to companies focusing on transport, logistics, healthcare, energy, retail customer, telecommunication or security. Every year, Esri re-invest 27.5% (before taxes) of their revenues in R&D.

The European GIS market

No data for Europe only was found. This section focuses on the Technavio figure for the overall GIS market for Europe, Middle East and Africa. However, Europe is expected to be by far the main contributor to the GIS market value for EMEA. The same approach was used for the EMEA than the one used previously for the worldwide GIS market. In this context, this section will give less detail on the type of categories.

[45] *Source: Stakeholder consultation (Esri)*

Figure 20 gives an overview of the split of revenues between countries such as UK and France and region such as Central Europe or Middle East.

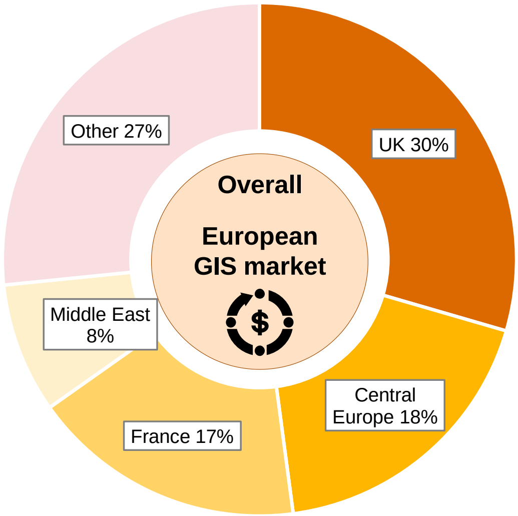

Figure 20: Split of revenues for countries or region within the EMEA (Source: Technavio, 2016)[46]

The category "Other" includes revenues from countries such as Spain, Sweden, The Netherlands or Russia or regions such as Africa.

The current market of GIS market for EMEA is valued at USD 3.211 billion and it is expected to grow at USD 5.016 billion by 2020, with an average CAGR of 9.33% over the period 2015-2020. Figure 21 gives an overview of the GIS market segmentation in EMEA.

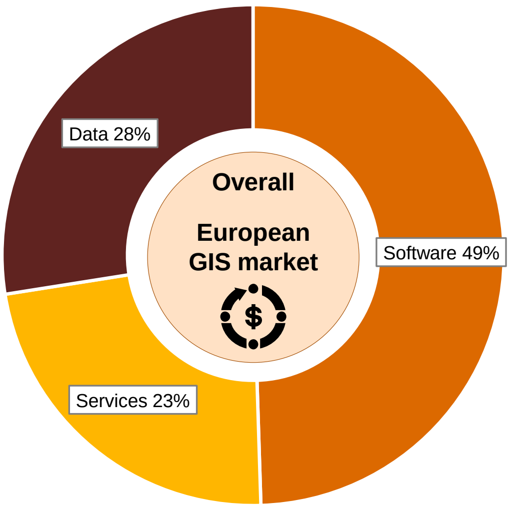

Figure 21: GIS market for EMEA by product segmentation (Source: Technavio, 2016)[46]

The result is fairly similar to the worldwide GIS market, highlighting the fact EMEA seems to follow the overall GIS market trends. Without giving details on each category – please refer to the previous sub sections for more details on product segmentation – the EMEA market is split as followed:

- GIS software: USD 1,589.44 million (49.50%);
- GIS data market: USD 883.03 million (27.50%);
- Services data market: USD 738.53 million (23.00%).

The chart below represents the main European GIS end users, led by government (15%), utilities (13.70%) and natural resources (12.80%).

[46] *Source: Technavio, 2016. Overall GIS market.*

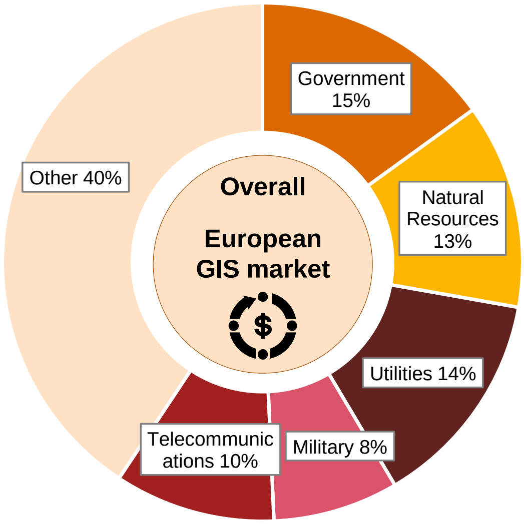

Figure 22: GIS market for EMEA by end user segmentation (Source: Technavio, 2016)[46]

As stated earlier, the European GIS market is fairly similar to the overall GIS market. This market is currently impacted by new trends derived from the ICT market related to cloud-based storage, on-the-cloud processing and web analytics platforms. More details on these new trends are developed in the chapter "***Data Access and Data Dissemination***".

The Copernicus programme at the crossroads between the EO and the GIS communities

The Copernicus programme reflects the current context where boundaries between EO downstream, GIS market and downstream market are blurring. The problems to be solved by the society are more and more complex, such as climate change or water management. EO plays a role in most of the main challenges faced by the 21st century, but this source of data is only one part of the solution; imagery has to be mixed with a vast variety of other data and integrated together to respond efficiently to such complex problematics.
The Copernicus programme is the first programme by its size and scope to have tried to connect the traditional EO downstream market with the wider GIS ecosystem. Responding to today context of digital economy and Big Data paradigm, the Copernicus programme is an EO programme offering way more than regular EO data. The model of the Copernicus programme is unique, bridging many user communities both from the public and private sectors. The European Commission is managing the Copernicus programme and its 3 main components: Space, Services and In-situ components. All the details related to data access and data dissemination for the Copernicus programme can be found in the next chapter "***Data Access and Data Dissemination***".

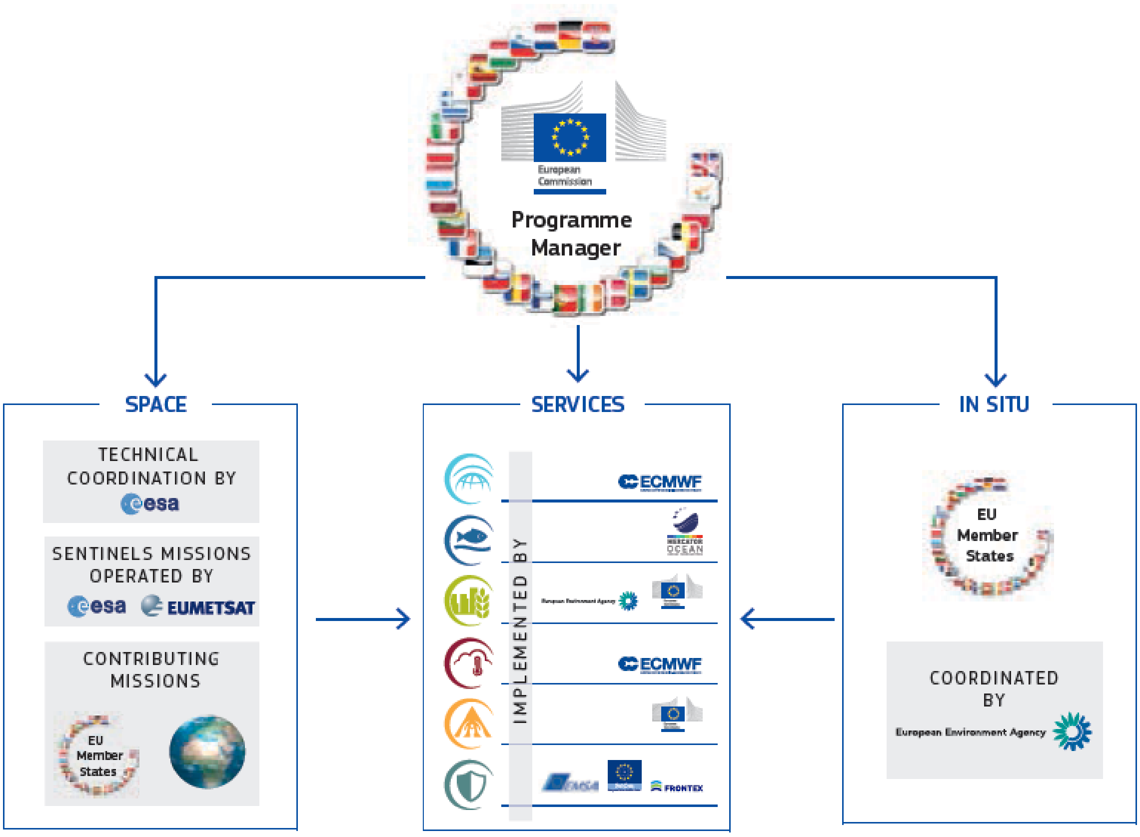

Figure 23: The overall structure of the Copernicus programme (Source: GEO, 2016)[47]

The Copernicus Space Component includes the procurement, the launch, the operation and the distribution of Sentinels data and contributing missions. The technical coordination and procurement for the Sentinels fleet are led by ESA and operated by collaboration between ESA and EUMETSAT. This element also includes the procurement of the overall space infrastructure, including satellites design, satellites manufacturing (procurement to the industry), satellites launches and ground infrastructure manufacturing (procurement to the industry). Finally, ESA is also in charge of acquisition, storage and distribution of the Sentinels data via the ESA Scientific Hub platform. ESA being a transnational space agency collaborating with all the European national space agencies, the organisation has access to many national EO data programme, including their archives. This additional data source is called contributing missions and provide, for registered users, access to a wide range of commercial EO data sources including SPOT, TerraSAR or Radarsat 2. This data source can offer in some cases higher spatial resolution

[47] *Group on Earth Observation (GEO), 2016. Cross-cutting Coordination of the Copernicus In Situ Component.*

than the Sentinels spacecraft, bringing interesting value for end-users. However, the access to contributing mission is based on restrictions and so not fully open to everyone.

The Copernicus In-situ component offers an access to observation from the ground, sea and airborne sensors but also reference and ancillary data licensed. The in-situ component supports the space component to offer access to sustainable and reliable data to produce, validate and calibrate Copernicus products for the services component. The In-situ component is implemented in two tiers:

- At the level of the service: each core service is in charge of daily operation and ingestion of specific in-situ data of interest per problematic (marine service, land monitoring … etc.) to offer valuable products for their end-users. This means that specific sources of in-situ data are tailored for each core service;[47]
- At the programme level: the European Environment Agency manages the cross-cutting service offering general in-situ data accessible through specific agreement with data providers/networks at programme level.[47]

The Copernicus Services component aims to deliver data and products freely available for a wide variety of users. These services integrate together data from the Space and In-situ components in order to offer Copernicus products tailored to the needs of very specific end-users. To better reach end-users, six different core services were developed or are currently being developed in different areas:

- Atmosphere monitoring (Fully-operational since 2015);
- Marine environment monitoring (Fully-operational since 2015);
- Land monitoring (Fully-operational since 2012);
- Climate change (Development phase);
- Emergency management (Fully-operational since 2012);
- Security (Development phase).

Each of the six core services responds to a very specific problematics identified as key for the European society. The services were designed to respond to very specific needs of the research and scientific communities, mainly related to the environment monitoring. However, the quantity and quality of the data and products offered by services perfectly suits requirements of private end-users. **The present report aims at assessing the revenues enabled by the availability of both Copernicus data and products for public and private end-users.** The content of the six different type of services will be explained more in details in each value chain under scrutiny in the chapter "***Analysis of Copernicus opportunities on sectoral value chains***".

Conclusions

The EO downstream market has continuously grown over the last decades and is expected to keep growing over the next 5 years with an average CAGR of 14.11% on the period 2015-2020. Estimated at USD 3,050 million in 2016, the satellite-based imagery market is expected to grow up to USD 5,900 million by 2020.

New competitive dynamics are impacting the structure of the EO downstream market traditionally based on a multitude of small and very small entities, both public and private. Over the last decade, European and Canadian manufacturers companies have moved down the EO supply chain, attracted by high margin and interesting market growth on the EO downstream market. Their strong financial resources have enabled them to acquire market leaders, leading to a strong consolidation of the market. The US market has seen the same consolidation trends through a number of acquisitions by DG, the EO downstream world leader. DG is nowadays the US national champion when it comes to imagery.

The new UAS-based imagery should have a very strong impact on the near-real monitoring of very high resolution imagery. The market is not yet mature enough to new real business propositions but these new airborne sensors are expected by experts to have a huge positive impact on the demand for imagery in the next 5 years. One of the most important barriers for the moment is based on national air regulations that do not allow commercial use of drones. On June 21 2016, the US Department of Transport's Federation Aviation Association (FAA) has released first operational rules on commercial drone activities for UASs smaller than 55 pounds.[48] This decision may have a very positive impact on other nations in the process to legislate the UASs commercial use.

Boundaries between EO downstream and GIS markets have started blurring over the last 5 years and this trend should increase in coming years. The EO 2.0 companies have already made the switch to this very promising market of USD 7,610 million in 2014, which is expected to reach USD 14,625 million by 2020.[49] Imagery being at the heart of GIS products, this market brings very interesting opportunities for EO downstream companies, leading to a strong increase in imagery and specific processing demand. This market is heavily impacted by the new ICT trends related to cloud-based storage, web analytics platform and on-the-cloud processing.

The "*Earth Observation Downstream Market Characterisation*" chapter is focusing on the internal dynamic of the market structure and the emergence of a multitude of new data sources. The main disruption on the EO downstream market is linked to the intersection of cloud computing, computing power, software and EO. The new platform paradigm is a real breakthrough on the EO downstream market that may completely disrupted the way users' access, visualise and use EO data in the future. The next chapter presents and analyses how data is accessed and distributed in general on the EO downstream market and in the Landsat and Copernicus programme. A specific emphasis is given to the new trends impacting the EO downstream access and distribution of data that are leading to the platform paradigm. Finally, the Copernicus programme is analysed more in depth in this context of new platform paradigm, looking at specific access & distribution parameters of the Scientific Data Hub platform, the current web-portal to access Sentinels data and products.

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[48] *Source: FAA official website, consulted June 22, 2016*
Link: https://www.faa.gov/news/press_releases/news_story.cfm?newsId=20515
[49] *P&S Market Research, 2016. Published on PR News Wire website, February, 4 2016.*
Link: http://www.prnewswire.com/news-releases/global-geographic-information-system-gis-market-expected-to-grow-at-11-cagr-during-2015---2020-ps-market-research-567650721.html

Part (c) – Data Access and Dissemination

Data access and dissemination is essential for any EO mission. The value of a free and open data programme is derived from the usage of data since the price mechanism is not working: the more the data is used, the larger the value of the programme is. Such type of data policy requires dedicated data access infrastructure to foster the dissemination of EO data into different communities of users.

This chapter puts in perspective the data access and dissemination infrastructure in the EO downstream market and in the two largest open EO data programmes in the world, the Landsat and Copernicus programme. The first section introduces the concept of data access, data distribution and data exploitation. It is afterward looking at the data exploitation chain of the EO downstream market, with a specific focus on the new trends in the data distribution and access infrastructure disrupting the market. The two following section focus on the two EO open data programmes. A section is dedicated to the Landsat data access infrastructure in order to understand how USGS is dealing with data dissemination. Finally, the last section focuses on the data access and dissemination of the Copernicus programme, analysing and comparing it with Landsat.

Data access and data dissemination on the EO downstream market

EO missions have an initial operational phase in which the data produced by the on-board instruments are validated on the ground once acquired. This phase is required to validate the data and insure reliability and quality of the EO data. The validation phase is executed by the entity running the operation of the programme, called **mission Principal Investigator (PI)**, involved in the design and development of the EO instruments[50].

Once validated, the data are made available to the users in two possible ways:

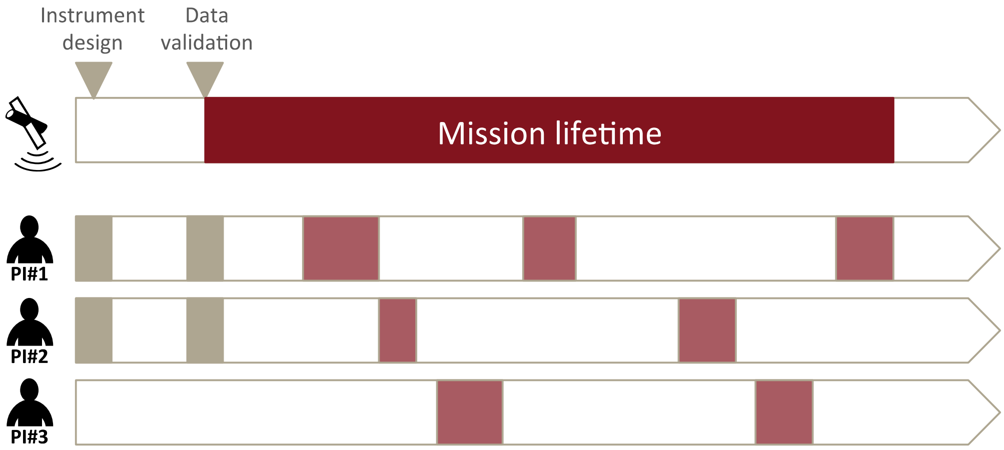
- **Near-real time**, the data are generated on board, received on the ground, processed and immediately made available via the mission ground segment. This data access model is only possible during the mission operational phase;
- **Long-term data access**, the data are made available providing access to the mission archive database. This data access model is possible to be provided both during the mission operational phase and after the end of the mission, if the mission archive is made available and the data are preserved.

EO-based applications vary a lot depending on the type of data access (near-real time vs. long term access). For example, applications related the analysis of change detection over time do not require near-real time data. Having access to an archive with long experience is way more valuable for such a type of applications. Such access enables change detection in vegetation, soil or water over time, leading to a wide spectrum of applications ranging from Oil & Gas survey to archaeology. On another hand, diverse EO-based applications do not derive any value of long-term data access and require near-real time data. Finland for example is 90% dependant on sea transportation for its exports and imports. In this context, monitoring of icebergs and sea's ice thickness in near-real time to support icebreakers is key for the economy of the country. A recent study from EARSC and ESA estimates that between EUR 24 million and EUR 116 million are generated in Finland and Sweden thanks to the use of satellite radar imagery.[51] Having access to an archive of old data do not bring any value for icebreaker activities. Disaster monitoring and response is another example where near-real time data are required for obvious reasons.

[50] *Strategy&, 2015. Study to achieve an increase in the scientific exploitation of data from European space missions. Report prepared for the European Commission Enterprise and Industry Directorate General.*
[51] *EARSC, 2015. Winter Navigation in the Baltic Sea. Prepared for the European Space Agency. September, 2015.*

Near-real-time data access

Near-real time data access is mostly implementing for EO programme using **multi-Principal Investigators (PI) model**.



Instrument tasking

Figure 24 - Multi-PI data access

The **multi-PI model** grants access to the PIs involved in the mission's design phase but also potentially, depending on agreements, to other PIs who did not support this phase. These PIs have access to specific slots of observation time during the mission, meaning they can request specific observations to be made at specific times- **this capacity is also called tasking capacity**. To summarise, the multi-PI model enables different entities/nations to share tasking time among a given EO programme lifetime. However, the observation time reserved by PIs does not cover the entire observation time available. Therefore, some PIs not involved in the early phases of the mission may be able to request specific satellite tasking. Depending on the PIs involved, accessing the satellite tasking can be free or fee-based. For example, CNES (the French National Centre for space studies) charges **1 EUR per squared kilometre and per acquisition for its own EO missions.**

Free access to EO data through open EO data programme is seen more and more as a "service" to the community, granting in near-real time data access to the widest possible audience. In the case of the Copernicus programme, providing near-real time access of such an amount of data brings a **lot of requirements related to automatic processing capacity** and **require high downloading rate** to facilitate the fast access to data. These elements are analysed more in depth in the next sections.

Long-term data access

The long term data access, or archives, requires three conditions to be satisfied

1) After data processing during the mission, the EO data are **preserved and made accessible** by means of an appropriate **data infrastructure**
2) The data policy applicable to the mission allows for the data to be made available to PIs that are distinct from the mission PIs.
3) There is a budget allocated to the implementation of the long-term data access.

The preservation of the data requires the implementation of dedicated data infrastructure enabling near-real time processing, distribution and long-term access. This infrastructure is influenced by the history of data preservation in a specific domain or country and by the volume of data to be preserved.

Access to long-term data requires dedicated funding mechanisms to maintain data access. A programme such as Copernicus for example requires dedicated and significant budget just to maintain the archives stored and available for everyone. The joint-collaboration between EC and ESA around the Copernicus programme aims at insuring continuity of long-term data access for the communities of users. The continuity factor is one of the most important factors valued by the Copernicus users. The long-term data access brings **several issues in terms of storage capacity and cost**, especially strong in the case of the Copernicus programme. These elements are analysed more in depth in the next sections.

Data exploitation chain

From acquisition to utilization of data, several interconnected stages and processes are involved. The four mains stages are represented below in the data exploitation chain. This section focuses on the theoretical data exploitation chain in the EO downstream market, and the data infrastructure related to it.

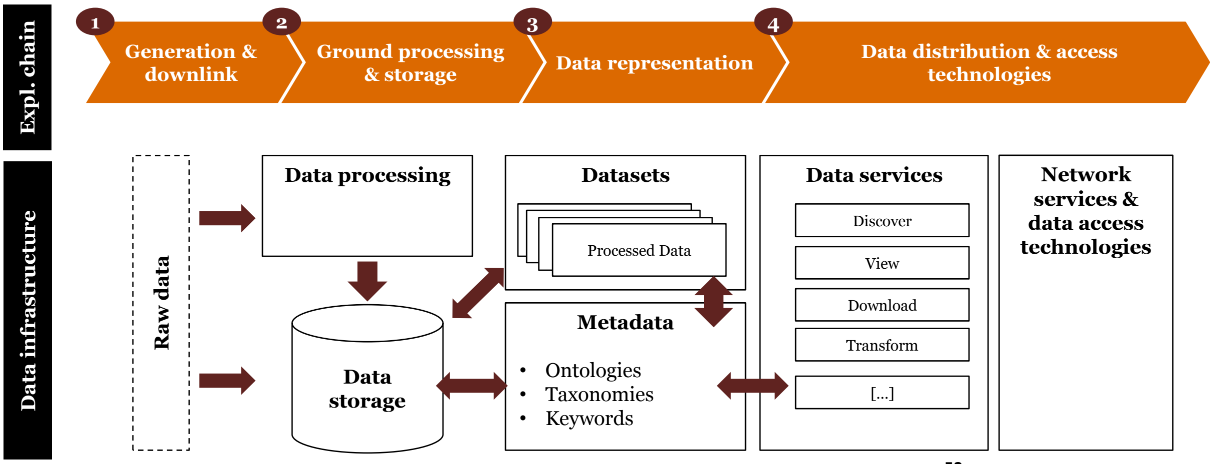


Figure 25 - Data exploitation chain (Source: Strategy&, 2015)[52]

The data exploitation chain is applicable to all type of EO programmes, the restricted (public and private) and the open ones. It is important to understand the fact that this chain materialise all the activities performed from the acquisition up to the distribution and access to data as if it was a linear process but this is not the case. The data exploitation chain works in both directions, from left to right and from right to left up to stage 2 (data storage). It is in fact a feedback loop: the user accesses the data, downloads it and can then extract it and re-process it at a high processing level. He/she will have to store it again in its own storage capacity and make it available for end users. The next sub-sections focus on the different levels of processing and the concept of the data exploitation chain, explaining in more depth each of the four stages.

Processing level of EO data

A satellite provides initially raw data to ground stations, based on specific acquisition requirements from satellite operator. However, the value derived from EO data is linked to the different levels of processing make on-the-top of the original data. Figure 26 gives an overview of the six EO data processing levels from raw data up to geo-information product. Note the levels of processing is not a standard accepted worldwide, many countries have their own typology of processing level.

[52] *Strategy&, 2015. Study to achieve an increase in the scientific exploitation of data from European space missions. Report prepared for the European Commission Enterprise and Industry Directorate General.*

	Level	Definition
Raw	Raw data	Payload data in their original format as received from the satellite
Primary	L0	Raw data or reconstructed (i.e. uncompressed, removed communication artefacts, formatted headers) and time-sorted raw data
	L1 (a,b,c,d)	L0 data reformatted, calibrated, geolocated, time-referenced, and annotated with ancillary information
	L2	Derived variables from L1 source data with the same resolution and location (e.g. instruments counts of L1 data)
Processed	L3	Processed L2 data (e.g. variables mapped on uniform space-time grid scales)
GEO-info Products	L4	Model output or results from analyses of lower-level data (e.g., variables derived from multiple measurements)

Figure 26 - The 6 levels of EO data processing (Source: Strategy&, 2015)[50]

Generation and downlink

EO satellites continuously monitor Earth surface and produce data which are then downlinked to ground stations. The data generated are classified as raw data using international industrial standard format ISO (International Organization for Standardization).

Raw Data	Payload EO data in their original format as received from the satellite

Table 8 - EO data processing level of link 1

Ground processing & storage

Once the raw data is received by the ground station, the data are processed to be transformed into Level 0 EO data. This activity is not a real transformation of the imagery; it is rather a re-integration of the data that were separated in individual packages to facilitate the downlink. This process is fully automatic every time the ground station is receiving EO data from the satellite; it converts raw data into level 0.

Level 0	Reconstructed, unprocessed EO data at full resolution, with any and all communications artefacts removed. This includes, but it is not limited to, duplicate data, synchronisation frames and communications headers.

Table 9 - EO data processing level of link 2

Once the raw data has been transformed into level 0 EO data, the original data is usually deleted to limit storage cost and capacity. PIs usually conserve level 0 and level 1 data in their repositories, but no raw data. Raw data and level 0 data do not bring any value for end user but there are still mandatory steps of the processing activities to facilitate the data transfer and downlink thanks to their original format.

Data representation

The data representation is the data exploitation stage where data are organised into meaningful sets. The first step of this stage is processing level 0 EO data into level 1 data through different processes such as calibration, geo and time referencing and annotated with specific information. Even if level 0 data do not bring any value, such type of data is usually conserved and stored by PIs to keep a repository of data in case of loss of level 1 EO data. Once the first step performed, EO data can be processed up to level 4 transforming a data into scientific or business intelligence depending on the willingness of the PI in charge of the programme or the information required by the end user. Table 10 gives an overview of the different EO data processing level.

Level 1 (a, b, c, d)	L0 data reformatted, calibrated, geo-referenced, time-referenced and annotated with ancillary information
Level 2	Derived variables from L1 source of data with the same resolution and location

	(e.g. instrument counts of L1 data)
Level 3	Processed L2 data (e.g. variables mapped on uniform space-time grid scales)
Level 4	Model output or results from analyses of lower-level data (e.g. variables derived from multiple measurements)

Table 10 - EO data processing level of link 3

Once transformed into the required level of processing, the processed data can be integrated into specific datasets related to the design of the EO mission. Each programme is focusing on specific problematics chosen by the PI funding the initiative. These datasets are then identified and transformed in metadata using a dedicated format facilitating exploitation by end users. These metadata are then provided with a specific definition and/or keywords to be easily identified by the user looking for a specific type of sensors, geographic areas or time series. Metadata facilitates the classification and the development of catalogues, facilitating the exploitation of data. PIs use accepted ontologies and taxonomies to facilitate interoperability with other programmes. Metadata are then stored by the PIs in charge; in most of the cases, metadata have a bigger **volume** than the original data.[50] The long-term preservation of data access for such type of files in EO programmes **brings important issues in terms of storage capability and costs**. As an example, the Copernicus programme is expected to be the 3rd largest data provider in the world in the next years, with 8 Petabytes produced per year, and the largest EO data provider in the world. **Transforming all these data into metadata files requires strong computing power and processing capabilities for near-real time data access** but it will bring **very important storage costs and capability requirements in long-term data access**. These problematics and how they were faced by the Landsat and the Copernicus programmes are explained more in depth in the next sections.

Each programme varies in terms of processing level offered to end users. The bare minimum offered by an EO programme is always level 0 data, even if most users, both scientific and private, are requiring higher level of processing. **The data representation stage of the data exploitation chain is where boundaries between public and private start to materialize and need to be carefully analysed**. Even if a programme such as Copernicus is providing several advanced data-sets through its core services, PIs in charge of the programme are **trying not to compete with intermediate users of EO data in order not to harm private initiatives**. Hence, open EO data programmes can be seen as a **complementary access to data for intermediate users**. They can access specific metadata of level 1 or 2 products, download them, extract the data, processed them up to level 3 or 4 and then provide the outputs to their customers. Indeed, EO open data programmes provide sets of primary data that require further analysis to bring value to a non-EO expert entity. In fact, **more and more end users are interested by L4 products**, which means that a final **product that can be directly applied to their specific business situation**. Many private entities which see potential value in EO data are not experts in EO processing and are not willing to invest in such capabilities. However, they are very **interested to pay in order to access directly to a specific business intelligence derived from imagery**.

Data distribution & access technologies

At this point in the data exploitation chain, all of the automated data processing is complete. The pre-defined datasets have all been generated and archived, and they are ready to be used. Before that can happen, users need to be aware of the availability of such data and they need to be able to search for specific data of their interests. Data distribution and access technologies are used to foster the downloading and so the utilisation of EO data. It procures the end users with different data services, as presented in the chart below.

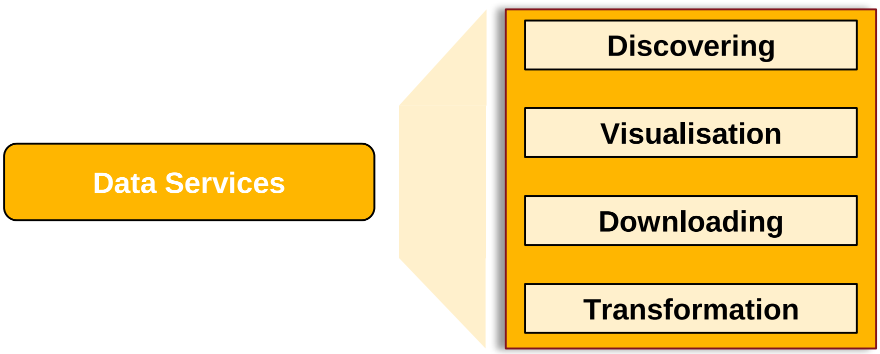


Figure 27 - Data services

Being able to discover the data is key for end users. Web-based platforms provide the access to EO data where end users research specific metadata based on orbital information, grid reference, geolocation information, quality information, fixity information and representation information. There is no centralized platform or a "one stop shop" for EO products commercially and/or freely available. This can make research complex for the end users which do not always know where to find the relevant information. Once discovered, the search engine could make preview visualisation of data available for the users. This feature does not always exist on all portals since it requires a powerful interface to be run. However, visualisation of data requires dedicated tools, such as Sentinel-1 or 2 toolboxes, to extract the information once the file has been downloaded. Finally, transformation activities are in end users' hands and it is not part of the data exploitation chain. Once the data has been downloaded, end users can require higher level of processing or add new layers of information (adding new sources of data for example) by themselves or paying an EO downstream company to do it for them. The process is then back to the data representation stage within the data exploitation chain – see previous figure for more details.

The dissemination of data is intrinsically linked to data distribution infrastructure and access technologies. The technology is usually procured by private companies, the ICT industry already having powerful and ready to use technologies able to respond to the largest needs of open EO data programmes such as Copernicus. However, data distribution and access infrastructure can be operated by public organisation(s), private organisation(s) or by Public-Private Partnerships (PPP). Large open EO data programmes such as Landsat and Copernicus are respectively operated and distributed by the USGS in the US and ESA in Europe but sharing data access infrastructure with other agencies in the US or Member States in Europe.

New trends related to Big Data and cloud computing are disrupting the way users discover, visualise and even transform EO data on the EO downstream market. In the most advanced private initiatives, downloading the data is not even required anymore, working directly on web-based platforms using cloud-based processing. These trends are presented in the next section.

New trends on data distribution and data access

This section focuses on the new trends that are heavily impacting the data distribution and access technologies of EO data. The traditional EO downstream value chain could be characterized by visualizing a linear, sequential flow of activities; this straightforward set of segregated activities carried out by separate actors in the value chain is now changing into a more complex setup. Even if digital image processing itself is globally performed the same way, new trends, inside and outside the EO downstream industry, are strongly impacting data distribution and access technologies, creating new competitive dynamics on this market, which are disrupting the traditional EO downstream market and offering new growth opportunities for both EO and new, non-traditional actors. When relevant, links and implications for the Copernicus programme are highlighted, especially related to the access and dissemination of Copernicus data through the web portal Science Hub, which is the main platform (operated by ESA) to access Copernicus data and products.

Big Data trends

In today's digital era, the multiplication of autonomous systems, Internet of Things (IoT) devices, open data programmes and other sources of data enable individuals, governmental organisations and companies to have a tremendous volume of data for free or at a very small cost. The complementary values coming from these different sources of data bring very promising business opportunities for Big Data applications. The Big Data technologies and services are expected to grow with a CAGR of 23% over the period 2015-2019, reaching USD 48.6 billion by 2019 according to the research firm IDC.[53]
Figure 28 summarises the key characteristics of the Big Data paradigm, the 5 Vs: Volume, Variety, Velocity, Value and Veracity of data.

53 Olavsrud, T. IDC says big data spending to hit $48.6 billion in 2019. CIO. November, 11 2015.
Link: http://www.cio.com/article/3004512/big-data/idc-predicts-big-data-spending-to-reach-48-6-billion-in-2019.html

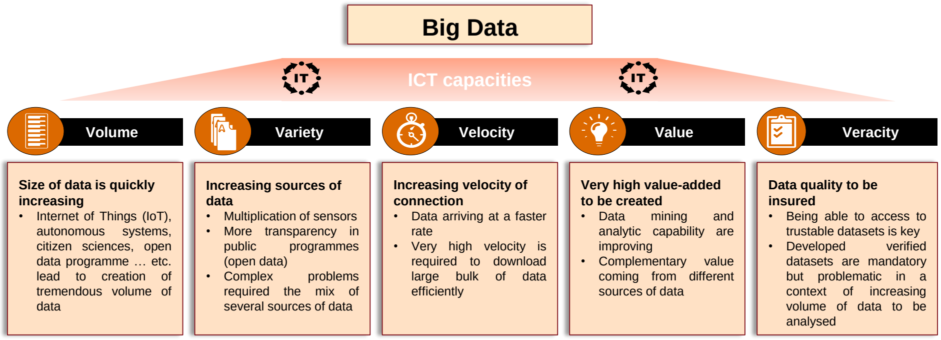


Figure 28 - The five Vs of the Big Data paradigm (Sources: PwC-Strategy&, inspired by ESA and SAC (2015))[54]

These five core characteristics offer very interesting opportunities but also raise issues inherent to Big Data trends. The information layers brought by the increased volume, variety and velocity of data require powerful computing and analytics power to capitalize on multiple sources of data. Another issue with Big Data is related to the current structure of the Internet which is based on Web Wide Web (WWW) technologies. Such structure is dominated by unstructured and semi-structured architecture built around hyperlinks and operating in silo. To summarize, WWW focuses on the structure of the data but it does not aim at understanding the data. On another hand, the semantic web focuses on the meaning of data to provide connected data sets. Semantic web technologies are emerging now and they are expected to bring very large value for the use of large volume of data derived from many different sources.[55] Natural Language Processing[56] is a particularly interesting computer science discipline related to the semantic web that will enable large datasets to be interpreted by machines through algorithms. This means any user, regardless of the taxonomies or ontologies used, will be able to easily access the content he is researching, which is currently complex to implement on WWW technologies.

This last statement is very important for EO and especially for a programme such as Copernicus. As already mentioned earlier, the European programme is the **3rd largest data provider in the world**, with 8 Petabytes per year, and **the largest EO data provider in the world**. One of the main factors of importance for programme such as Landsat and Copernicus is the programme's continuity to build large archives. Such importance of continuity will bring important storage issues in the coming years with more and more Sentinels spacecraft providing data, plus the repository of former data. Raw EO data does not provide a significant value for users so these data need to be processed to be useful for end users. However, such large volume of data to be processed requires enormous computing power and time to be routinely processed to make Copernicus products available. **The current system does not enable such automatic processing of all the archives when all the Sentinels will be operational and continuously monitoring Earth in order to insure data value and veracity.** Copernicus' users raise concerns about the fact that the **current structure of the Copernicus infrastructure does not facilitate the access to Copernicus data and products** because the **downloading rate offered is not strong enough to lead to a low data velocity.** This observation is even stronger within the non-EO expert communities where Copernicus products are not used because of the data access platform considered as not user-friendly enough.

Large volume of data's users, both public and private, face major issues to download large bulk of data using the Science Hub portal. As discussed in the Landsat value-chain, USGS has developed an interesting way to counter this issue, offering dedicated bulk access for those actors. Access is negotiated on a one-by-one basis between the USGS and the organisation interested by large volume of data.

The economic and societal values of this market have attracted the interest of the European Commission. EC considers Big Data as a key economic asset to stimulate competitiveness, fostering the growth of the European economy and employment. In this context, **the Big Data Value Association (BDVA) represents the European Big Data community**, including public and private organisations (data users, data storage, data providers, data analytics, universities, research centres, etc.). The association gathers more than 120 members, including some

54 European Space Agency and Satellite Applications Catapult (2015). EO21: Indicator of Trends Report. Prepared by SAC, under assignment from ESA.
55 Cambridge Semantics. Website consulted June, 09 2016.
Link: http://www.cambridgesemantics.com/semantic-university/introduction-semantic-web
56 Natural Language Processing is a discipline in computer science related to computational linguistics, machine-learning and artificial intelligence. The aim is to create interactions between computers and human language to facilitate access to data.

non-European companies which have an important presence in Europe (research centres and business units) such as IBM (one of the funding members) or Huawei. Some fees associated to membership have to be paid by the companies who want to be part of BDVA. However, being a member of BDVA is not mandatory to apply for any Horizon 2020 (H2020) project. **The EC and the BDVA have set up together the Data Public Private Partnership (PPP)** which aims at bringing together the Big Data communities actors from the industry, academics and governments to make the supply and the demand related to European Big Data technologies meet. The rationale behind such an initiative is **to push for the development and the commercialisation of innovative European Big Data technologies and services.** Indeed, on the Top-20 companies on the Big Data market, only 2 are European companies[57]. This initiative aims at **developing European critical mass of experts in the field of Big Data, with a specific focus on the commercialisation part**, to nudge Europe to become a leader in such very promising market. This PPP was initiated within the framework of H2020 with a budget of EUR 1 billion with 50% funded directly by the industry and 50% by H2020 funding mechanisms. This initial investment is made to encourage an additional private investment, expected by the EC to be on a ratio of 4:1 (EUR 500 million from the EC and EUR 2 billion from the industry). The BDVA has specialised working groups, including one dedicated to space technologies and data led by the Romanian company Terrasigna. Discussions between BDVA, EC and ESA aim at assessing what can be done to connect the dots between the data PPP and the Copernicus programme. The BDVA seems to be a potential way forward to face the Big Data issues faced by the Copernicus programme, and enable the connection of the Copernicus programme distribution & access to the global data virtual ecosystem.[58]

Cloud Computing

In today's context of digitalisation of the economy and Big Data, access to scalable cloud computing power stimulates and facilitates the dissemination of EO data into wider communities. Cloud computing refers to the delivery over the Internet of hosted services enabling users to share computing resources without the need to build and maintain dedicated computing infrastructure in-house. Cloud computing is a direct response to some of the inherent issues of Big Data related to storage (volume) and access to data (connectivity and web semantic). It is firstly a new way to access data that facilitates storage in a context of increasing volume of data available. Users can access directly on the platform of the data without needing to download directly and store the data in their own hardware, bringing the cost of access to data down. It also facilitates the access of technical types of data for non-technical actors, especially in the case of remote sensing imagery (satellites and UASs), allowing such actors to access scalable computing resources directly on the cloud. Such capacity offers processing activities at very low cost which is at the end way cheaper for the user who does not need to acquire its own processing capabilities. It enables any organisation to have access to a wide range of sources of data (some platforms even enable users to upload their own data on the cloud) regardless of size & type of actors or their level of technicity. Figure 29 gives an overview of the different types of cloud computing services options[59]:

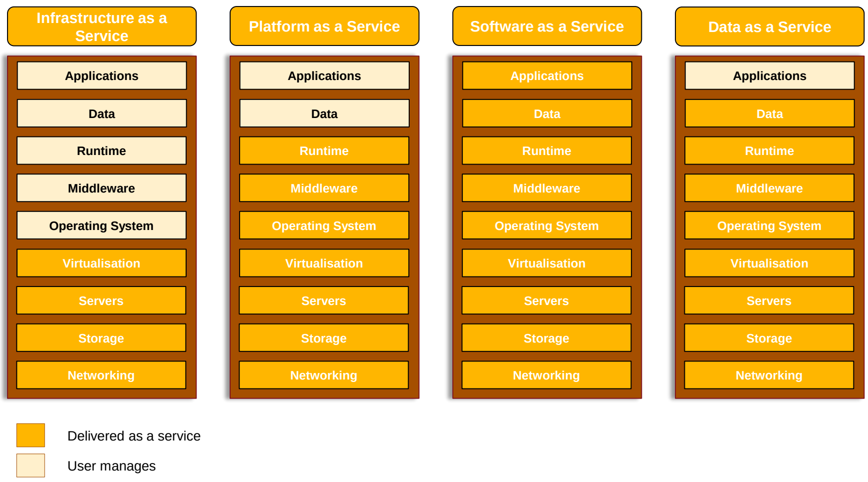


Figure 29 - Cloud computing services options (Source: adapted from Woodside Capital Partners, 2014, cited in SAC, 2015)[60]

57 European Commission website, February, 24 2016
Link: https://ec.europa.eu/digital-single-market/en/big-data-value-public-private-partnership
58 Sources: Stakeholder consultation
59 European Space Agency and Satellite Applications Catapult (2015). EO21: Indicator of Trends Report. Prepared by SAC, under assignment from ESA.
60 Woodside Capital Partners, 2014. "OpenStack: Is this the Future of Cloud Computing".

- **Infrastructure as a Service (IaaS)**: virtualised computing resources and on-the-cloud storage capabilities are directly hosted on the web by third party. This type of cloud computing service enables the users to access on-the-cloud infrastructure so if frees them from having to set-up in-house hardware and storage infrastructures. [61]
- **Platform as a Service (PaaS)**: PaaS is a category of cloud computing services where the platform offers various tools for coders and developers to create, run and develop applications for web and mobile. It is basically taking IaaS at the next level, offering both the hardware and the software for the user, and facilitating the creation of applications.[62]
- **Software as a Service (SaaS)**: SaaS enables end users to have access to a device with full functionality, third party providing from networking up to applications. It frees organisations to install and run applications on their own system, offering interesting cost reduction (no specific hardware to be bought and maintained, no software licences, no need for strong IT supports, etc.).[63]
- **Data as a Service (DaaS)**: this last cloud computing service is a type of service that has emerged recently with the increasing access to high-speed internet from all over the world and the maturity of service-oriented architecture. It offers a high mobility for data from one platform to another, limit redundancy of data and ease administration and accessibility. Compared to the three other cloud computing services, DaaS is expected to facilitate and increase efficiency of distribution and data processing.[64] Users can build on the top of this type of cloud computing service to create their own APIs (visualisation) and dedicated services & applications. These users can then propose their API to offer commercial or scientific functions (depending on the goal of the API's owner) to end users.[59] APIs also enable an easy and user-friendly access to a multitude of data sources, facilitating the integration of such sources to create high value-added applications or services.

The cloud computing services market accounts for USD 21.90 billion worldwide in 2016 with a tremendous CAGR of 21% over the period 2015-2020. The market should double by 2020, reaching USD 44.20 billion worldwide as stated in the chart below.[65] IaaS is by far the largest market and it is expected to remain the same over the next five years. No figures were found on DaaS market.

21% CAGR (2015-2020)

Worldwide Market Value
Cloud Computing Services

(B US$)	2014	2015	2016	2017	2018	2019	2020
PaaS	2,3	3,1	4,0	4,9	5,9	6,9	8,1
SaaS	3,1	4,1	5,4	6,8	8,4	10,0	11,6
IaaS	7,0	9,7	12,5	15,4	18,2	21,2	24,5

Figure 30 - Worldwide Market Value for Cloud Computing Services (Sources: adapted from Forbes)[65]

Cited in European Space Agency and Satellite Applications Catapult (2015). EO21: Indicator of Trends Report. Prepared by SAC, under assignment from ESA.
61 SeachCloudComputing, "infrastructure as a service (IaaS)", consulted May, 31 2016.
Link: http://searchcloudcomputing.techtarget.com/definition/Infrastructure-as-a-Service-IaaS
SeachCloudComputing is a reference website for cloud computing news, part of the TechTarget network.
62 SeachCloudComputing, "platform as a service (PaaS)", consulted May, 31 2016.
Link: http://searchcloudcomputing.techtarget.com/definition/Platform-as-a-Service-PaaS
63 SeachCloudComputing, "software as a service (SaaS)", consulted May, 31 2016.
Link: http://searchcloudcomputing.techtarget.com/definition/Software-as-a-Service
64 SeachCloudComputing, "data as a service (DaaS)", consulted May, 31 2016
Link: http://searchcloudapplications.techtarget.com/definition/data-as-a-service
[65] Louis Colombus. "Roundup Of Cloud Computing Forecasts and Market Estimates, 2016." Forbes. March, 13 2016.
Link: http://www.forbes.com/sites/louiscolumbus/2016/03/13/roundup-of-cloud-computing-forecasts-and-market-estimates-2016/#11b7f92974b0

A strong competition exists on the cloud providers such as **Amazon Web Services (AWS), Google, Microsoft, Oracle or IBM** which contributes to bring costs of storage down. AWS is the market leader in the cloud services market with 31% market share worldwide, followed by Microsoft (9%), IBM (7%), Google (4%) and Salesforce (4%).[66] Figure 31 presents graphically the competitive position of the 5 major cloud computing services firms and gives some insights on their growth rate. As stated earlier, the cloud based services market has a very strong growth rate but it can be noted that the five leaders on this market have even higher growth rate, led by Microsoft and its 124% growth rate in 2015, followed by Google Cloud Platform (108%), AWS (63%), IBM Cloud and SoftLayer (57%) and finally Salesforce (40%).

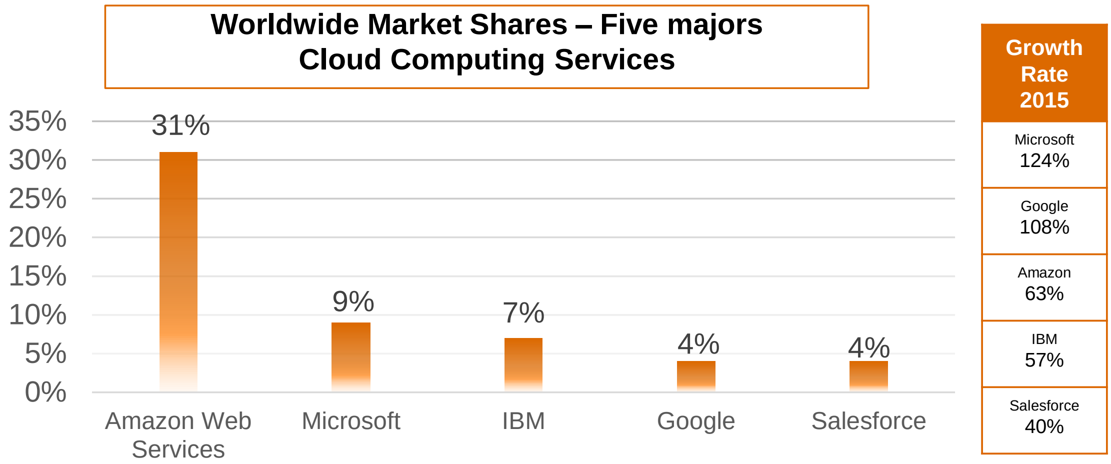


Figure 31 - Market shares and growth rate of the five majors cloud computing services companies (Sources: adapted from Synergy)[66]

This tremendous market growth and high competition stimulates the appetite for new platform features and new sources of data, especially for EO data, to diversify their offer of data. Open EO data programme such as the Landsat programme or the Copernicus programme brings very interesting opportunity for such actors to offer EO data on their existing cloud-based infrastructure at very low cost. Indeed, several cloud providers have already developed some initiatives to provide EO open data on their platform. The most advanced private initiatives related to EO are Amazon S3 and Microsoft Azure, both offering IaaS type of cloud services based on open EO data. These platforms were not developed specifically for EO data, the provision of such type of data is mostly enabling AWS and Microsoft to add a new feature on their platforms under the form of dedicated buckets of data (Landsat 8, Sentinel-1, Sentinel-2, etc.) where users can access very easily such type of data. These actors, at least in the case of AWS, Google and Microsoft, are not interested in providing processing activities or value-added services: they focus on offering an easy, cheap and fast access to data. It also brings interesting options for programmes such as Landsat or Copernicus to access new pools of users that they will have never been able to reach without such platforms.

A new perspective on the EO downstream market

The way EO data is used and accessed by end users is called to change drastically over the coming years. Innovative initiatives challenge the way data is distributed and how end users access EO data such as the Google Earth Engine or the digital platform Arc GIS. The future of EO should be capitalizing on the Big Data context and the availability at low cost of multitudes of data sources and computing & analytics power. This context is particularly interesting because it raises the interest of governments and industries which are willing to invest together to create a fertile ground for innovation and growth in Europe, notably through initiatives such as the Big Data PPP between the EC and the BDVA mentioned earlier.

Google Earth Engine[67]

The Google Earth Engine is one of the most well-known initiatives using remote sensing imagery, mostly based on Landsat and airborne data. Sentinels data also start to be incorporated to the platform which can stimulate the dissemination of Copernicus data. This initiative is particularly known because it is a free tool accessible to

[66] *Synergy Research Group, 2016. "AWS Remains Dominant Despite Microsoft and Google Growth Surges". Link: https://www.srgresearch.com/articles/aws-remains-dominant-despite-microsoft-and-google-growth-surges*
[67] *Source: Stakeholder consultation (Google Earth Engine)*

everyone. Google Earth Engine does not pertain to make money, it is a philanthropic tool used by scientists and researchers all over the world.

The Google Earth Engine has over 8,000 users on which approximately 2,300 are located in Europe. On these European users, 1,100 belong to universities, in fact more than 290 different European universities. Landsat and Sentinels data are freely available on the platform. Landsat collection has 1,300 users leading to more than 3 million scripts run using this collection. Sentinel-1 has over 200 users, with over 25,000 scripts run on the Sentinel-1 collection. The Google Earth Engine expects a much higher usage of Sentinel-2 data when the collection will be available on the platform.

Large ICT actors and data companies such as Google, AWS or Microsoft, are new comers on the EO downstream market. These innovative players facilitate the emergence of a new digital market for EO data, and for Big Data and Geo-spatial information in general. The chart below gives an overview of the two main enablers of digitalisation of the market related to the infrastructure and analytics platforms.

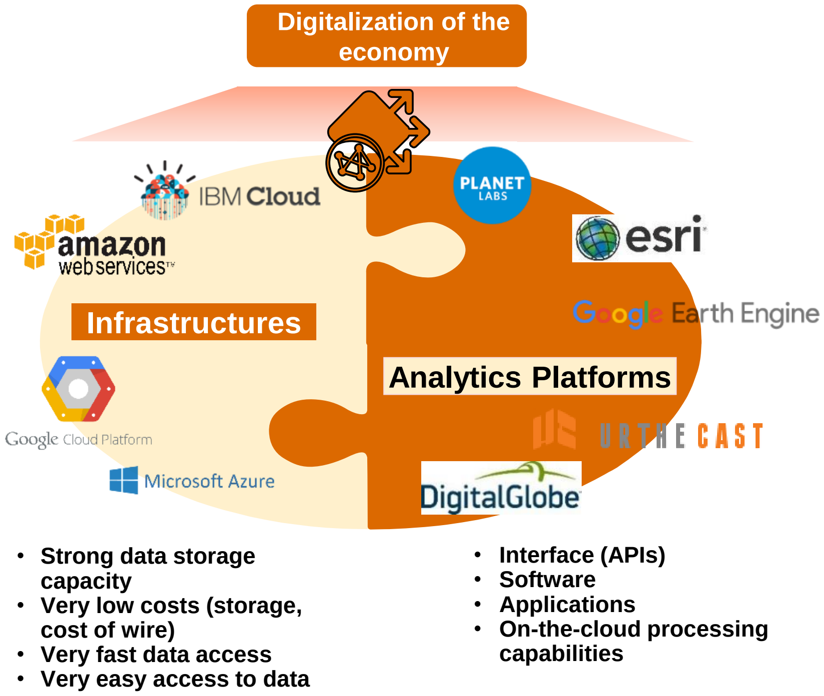


Figure 32 - Enablers of the market digitalization (Source: PwC-Strategy& analysis)

To be able to provide digital platforms, very powerful ICT infrastructures (storage, distribution, etc.) are required in the data distribution and access infrastructure. **Downstream actors build analytics platforms on the top of these infrastructures in order to provide Application Programming interfaces (APIs) that enable the visualization of data and, for most of them, offering on the cloud-processing capacity**. A large number of actors on the US EO downstream market have already started developing their own platform and some of them already propose some services and on-the-cloud processing, such as DG. The GIS market has already made the switch to the digital platform and the **GIS cloud market is already quite well developed, accounting for USD 519 million in 2015 and expected to grow up to USD 875.9 million by 2020**.[68] The new EO 2.0 actors have also already developed their own API interface, even in some cases their own ICT infrastructure. On a web-based platform, accessing other sources of imagery and other types of data is facilitated thanks to large repositories of data stored by large ICT actors. For example, the AWS S3 platform enables the users to access a large number of data buckets, including Landsat 8 and recently Sentinels 2 data, but also a wide range of different types of data. The users then need to build an API on the top of the AWS S3 platform to enable visualisation and transformation of data.

How are these trends materializing on the EO downstream market? This market is currently based on two main activities: **archives and tasking**. The first one relies on the automatic capture of imagery stored in public or private repositories for future analysis. The main goal of archives is to **maintain continuity in data acquisition of the same areas at different periods of the year to enable change detection activities**. The longer the archive

[68] *Technavio, 2015. Global Cloud GIS Market 2016-2020.*

is (time continuity), the more efficient the change detection activities will be. A programme such as Landsat brings very interesting value in change detection activities because the users can have access to data from 1972 until now, leading to very interesting outputs. The second main activity, which is also the most lucrative for the EO downstream market, is the tasking. **Tasking activities are on-demand services for actors with very specific requirements in imagery and in timing**, like Defence & Security users for example. The client can ask **a specific geographic coverage**, at **a specific spatial resolution of a given sensor and at a specific time**. From the end user point of view, the imagery is way more accurate compared to archive. The **tasking activities are also way more expensive** and it brings **some capacity issues for traditional EO downstream actors using large powerful satellites** because they have an inherent limit in terms of capacity. For example, if a given company has 3 satellites in orbit and many users asking for specific tasking activities in near-real time, some conflicts of interest may raise. Usually, Defence actors and large private companies are served first, paying the highest price. The new constellations of EO 2.0 actors may heavily impact this market, enabling a strong increase in tasking capacity. If such actors succeed to offer a cost-effective high tasking capacity, they will enable the creation of a commercial mass-market leading to important new streams of revenues for the EO downstream market. A dedicated case study focusing on EO2.0 companies is developed after this chapter.

In both cases, archives and tasking, the business-model is based on a pay-per-scene approach, where the end users pay using the regular $/km2. Figure 33 gives an overview of the different components of the EO downstream market.

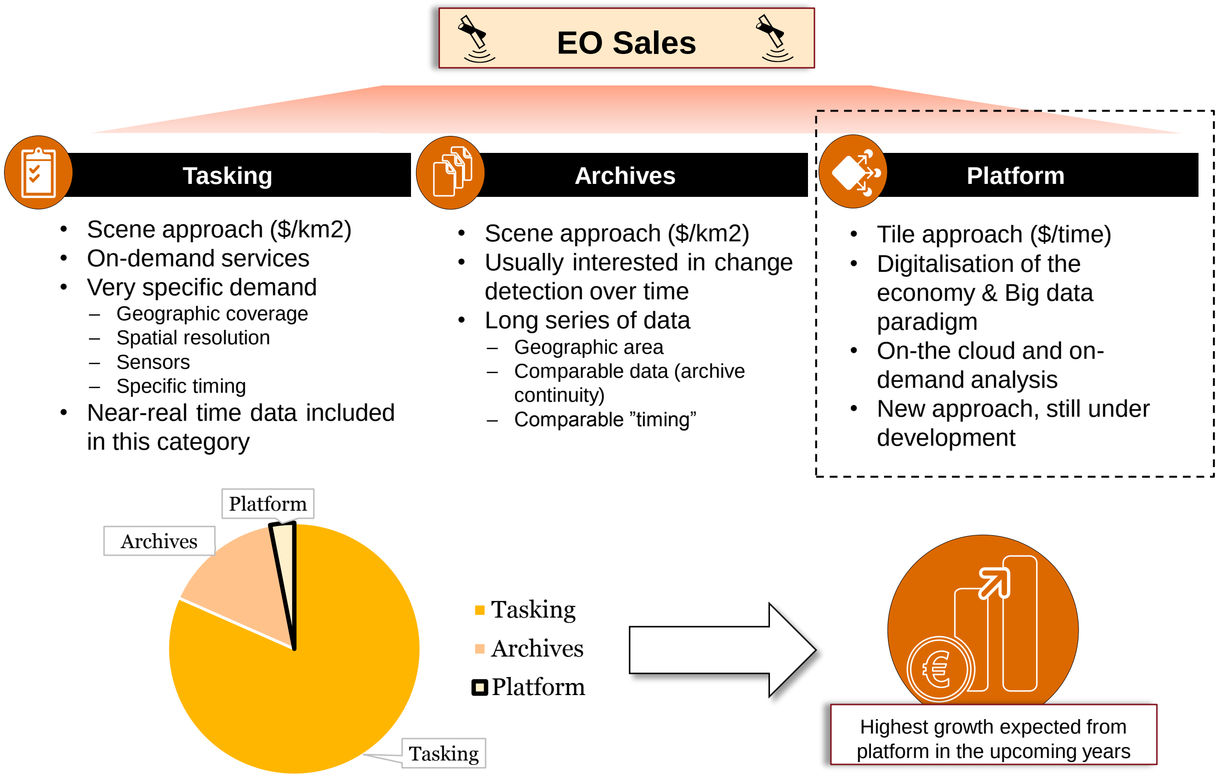


Figure 33 - The different components of the EO downstream market (Source: PwC-Strategy& analysis)

The last component of the EO downstream market, **the platform paradigm**, is the result of all the different trends highlighted earlier. It is **currently representing a tiny fraction of the EO downstream market**, as shown in the previous chart, but several EO downstream experts estimate that the highest growth is expected to come from this type of activity in the upcoming years[69]. This activity implies a switch of business-model from a scene approach, or pay-per-image, to a tile approach, or pay-per-access/pay-per-time. This new trend relies on **cloud-based platforms** enabling **on-demand analysis** and the creation of **synergies between multitudes of data sources**. On this particular activity, the end user is basically renting a given geographic area on a web-based interface for an amount of time, 3 months for example. Then, users do not pay per picture but the access to a given catalogue of imagery on the area chosen, receiving all the new updated pictures when available during the period of analysis. This new business model brings very interesting opportunities since it enables end users to have **access to strong cloud-based processing power with all the data required, such as L3 and L4 processing level,**

[69] *Source : stakeholders consultation*

updated every time new data from the selected catalogue is available, without any need of strong computing power or storage capacity. On another hand, it enables the EO services provider to have access to largest stream of revenues. Platform activities also facilitate the integration of different sources of data (**data variety**) without any need for downloading (**data velocity**) and storing data (**data volume**). Experts expect such type of platforms to enable the provision and integration together of the UASs data (when commercial regulation will be released), GIS products, Big Data analytic tools and the large numbers of parallel services enabled by such type of tools.

The switch of business-model has not occurred yet but interesting initiatives are already under development within EO downstream actors, especially through the **Geospatial Big Data platform of DG**. **This new component of the EO downstream market should be fully operational in the coming years, and will lead to an important disruption on the EO downstream market, offering new growth opportunities for the actors able to take advantage of this promising market.**

The Landsat programme

This section focuses on the Landsat data access and distribution infrastructure and the role played by the USGS. A particular attention is given to the dissemination of Landsat data and the type of products information provided by the USGS web-portal.

Role of USGS & Landsat data dissemination

The Landsat programme is a joint collaboration between NASA and USGS where NASA is in charge of procurement (satellite infrastructure and launch) and USGS in charge of operation and exploitation. The responsibility and role of USGS is related to the users of Landsat and can be summarised in two buckets: **archives & storage** and **utilisation of data**. The first one is a gatekeeper role, heritage of the Land Remote Sensing Policy Act, where USGS has the mission to conserve a physical repository of all existing Landsat data archives from all over the world centralised in EROS centre in the US. This role enables the long-term data access to all US users of all the Data produced by the Landsat programme from 1972 up to now. The second role of USGS is to foster the utilisation of Landsat data among individuals, communities and businesses. This role motivates all the strategic decisions taken by USGS related to the Landsat programme, including the **choice in 2008 to implement an open data policy through a web-based platform**. Since 2008, the White House has been pushing to foster the use of governmental data, increasing transparency in the public administration. The Freedom of Information Act states that public data (non-sensitive) should be made available for everyone as quick as possible to achieve a maximum of transparency. In this context, the cloud went from being evil to the best thing ever in the US government mind. Two federal laws legislating cloud (FISMA and CLOUD) were released in order to set up the minimum IT security requirements to do business with a US agency. Before the free data policy and the availability of the web portal, USGS was distributing 20,000 Landsat scenes per year. **From 2008 until 2016, more than 35 million scenes were downloaded**; the figure represents the number of Landsat scenes downloaded per year from the USGS portal since 2008.

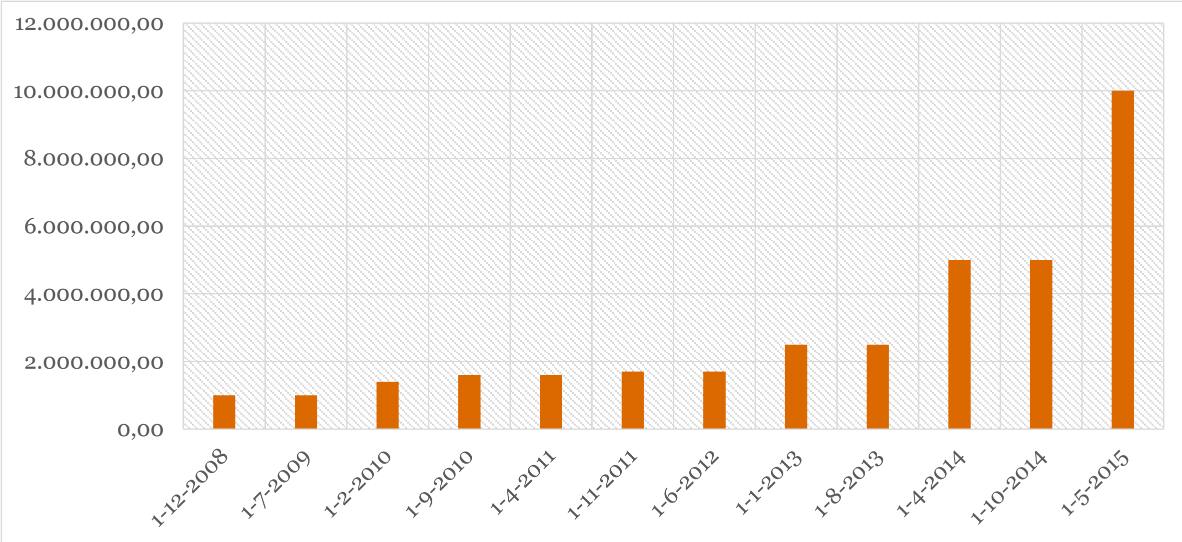


Figure 34 - Landsat scenes downloaded from USGS EROS centre per year (Sources: adapted from USGS; PwC-Strategy& analysis)

The chart highlights the fact rate that downloads are increasing year after year, reaching an average of almost 1 million scenes downloaded per month in 2015. A significant increase can be noted in 2014 and 2015 corresponding to downloading of large bulks of data from users such as AWS, Google Earth Engine, DG or Planet Labs. Note that Figure 34 does not include all the data downloaded through third party platforms such as the AWS S3 platform.
Figure 35 gives an overview of the split of users downloading Landsat data and products through the USGS web-based portal.

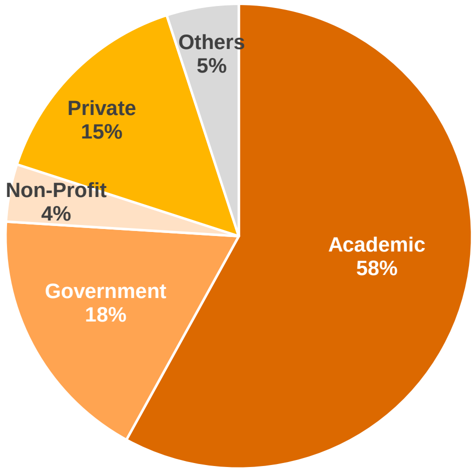


Figure 35 - Split of users downloading Landsat data through USGS web-portal (USGS, 2013)[70]

Less than 15% of Landsat users accessed data via the USGS infrastructure for commercial purpose while 76% of users are governmental or academic users. The Landsat programme being designed to have a particular attention to governmental and scientific needs, this split of activities makes sense. However, these figures focus only on the data access through USGS web-based portal, and not on private platforms such as AWS S3 or Microsoft Azure.

To foster the dissemination of Landsat data, USGS offers two specific accesses to better match its user needs: a regular channel and bulk downloading access. The chart below summarises Landsat data access channels.

[70] *USGS, 2013. Users, Uses and Value of Landsat Satellite Imagery, Results from the 2012 Survey of Users.*

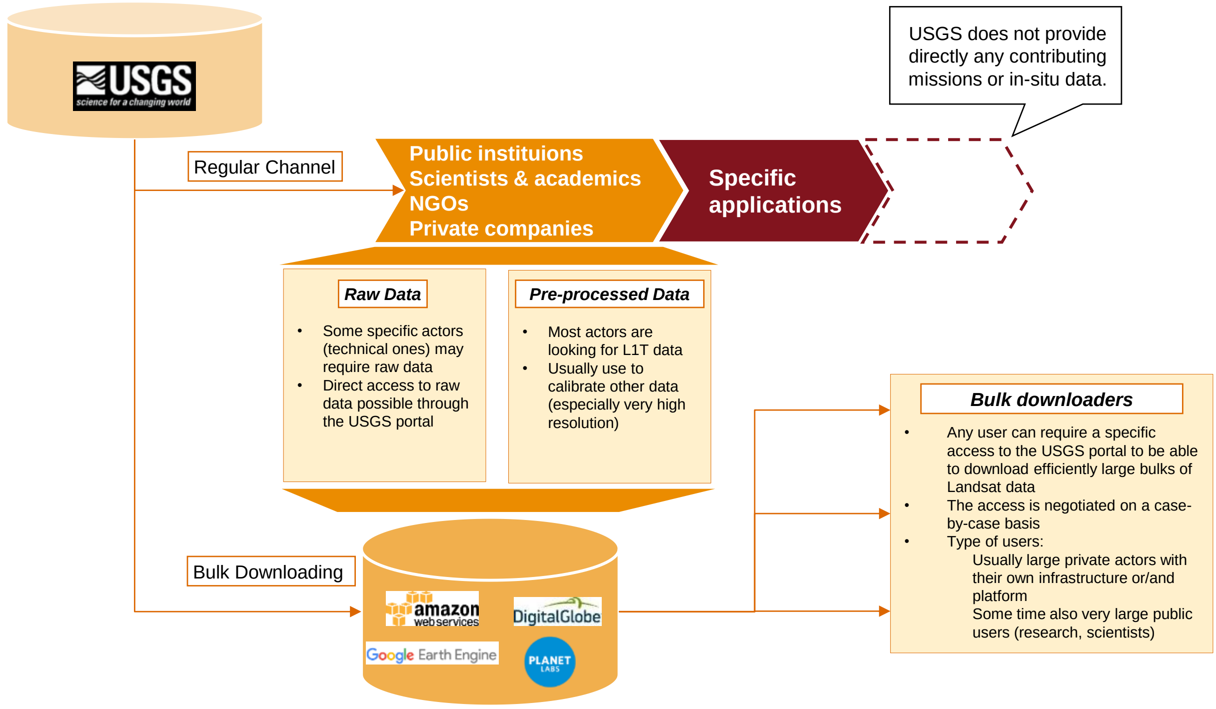


Figure 36 - Access to Landsat data & products via USGS portal (Source: PwC-Strategy& analysis)

Both channels enable the access to raw data and high level products (pre-processed data). Most of the actors require the L1T data, using them to calibrate other sources data, including high and very high resolution EO data. Some technical experts also require a direct access to raw Landsat data. The first channel provides a regular access to Landsat archives (Landsat 8 and former Landsat missions). This channel is designed for users with specific data needs downloading small amount of data. The regular distribution channel provides a connection too weak for users requiring large amount of data. Such type of users can require from USGS a dedicated access to the bulk download capabilities which are negotiated on a one-by-one basis. Private users, such as AWS, Planet Labs or Google, but also public users (universities, research centres, governments) have used or are currently using this tailored access to access large amount of Landsat archives. For both types of accesses, the US government pays for the online storage resources and outgoing network as part of the overall institutional infrastructure at the USGS EROS Center. Then, it is the users' responsibility to ensure they have the necessary network bandwidth and storage resources on their own to consume the desired volumes of data.

Products available on the USGS portal

Apart from raw data from all the Landsat missions since 1972, the USGS portal offers high level standardised information products (Level-1T), produced by USGS experts on a per-scene basis. Three main types of products are currently available on the USGS portal, including **burned area, dynamic surface water extent and surface temperature**. The science processing algorithms to elaborate these products and provisional products generated from Landsat TM (Thematic Mapper) and ETM (Enhanced Thematic Mapper) data have been developed and submitted to initial validation and stakeholder evaluation. All the algorithms are coded in open-source software publicly available on GitHub, an online collaborative platform of open sources projects for individuals, communities and businesses gathering millions of coders from all over the world.[71] The aim of such a strategy is to foster the use of Landsat data and algorithms pushing organisations on this platform to implement the codes on their systems. It is also a way for USGS to ensure consistency of products quality from multiple providers. The science processing algorithms are currently being revised to accommodate Landsat 8 OLI (Operational Land Imager) and TIRS (Thermal Infrared Sensor) data, after which provisional products will again be generated and made available for stakeholder evaluation. Once the stakeholder evaluations have been completed and the principal investigators have published their algorithms and produced uncertainty analyses in the peer reviewed literature, USGS plans a transition from provisional to operational product generation.

71 Source: Github website, consulted April, 28 2016
Link: https://github.com/

In addition to the higher level information products, **USGS is currently moving towards the generation of "analysis ready data"(ARD) –** ARD is also called data cube **–**to support Federal agencies in land change monitoring activities. ARD is used to make analysis of data easier, providing the user with a data base of a given geographical area such as United States, Central America or at continent-level. The aim of ARD is to provide a multitude of different information using different sensors and wavelengths of the same geographic area in the same data set using the same format which facilitates change detection for archives work. These data cubes are built with several dimensions, each one representing a different attribute in the data base, including time, sensors or wavelength. Having access to ARD make the access to data way easier for intermediate and end users, both public and private, enabling a time reduction in the search of data. For the prevision of USGS related to the Landsat programme, key elements of ARD should include radiometric processing to top of atmosphere reflectance and brightness temperature, atmospherically corrected surface reflectance and surface temperature. These data are gridded to provide a continental map scale projection, facilitating time series analysis and "pixel drill-down" activities.

The Amazon experience, a private distribution of the Landsat imagery

Since May 2015, AWS has set up new buckets on its **S3 platform** where users can have access to a large part of Landsat 8 archives downloaded thanks to the specific bulk-access they have negotiated with USGS. Many organisations, especially the private ones, are using the S3 platform to access Landsat data but also all the other buckets available on the platform (many sources of data are available on the AWS' platform). Then, **actors can build on the top of S3 platform an interface for data visualization** and many entities, such as Esri, MapBox or PlanetLabs, already use their own interface on the top of S3 platform (and potentially other platforms) to create value for their users.

Landsat 8 and the Amazon experience

Amazon Web Services (AWS) announced in March 2015 that it is now hosting Landsat 8 imagery on its publicly accessible Simple Storage Service (S3). With help from the White House Office of Science and Technology Policy and the U.S. Geological Survey – manager of the vast Landsat archive – AWS has made over 80,000 Landsat 8 scenes (~85 Tb worth of data) available as one of its AWS Public Data Sets, and hundreds of Landsat 8 scenes are being added daily – as they are collected, they are added. Each spectral band of each Landsat scene is available as a stand-alone GeoTIFF. AWS' streamlined access lets us process more images quicker and helps us deliver fresh insights about our changing planet to customers. As already highlighted previously in the section "Competitive dynamics: a new perspective on the EO downstream market", the results in the first 150 days for AWS were very good:

- Over 200,000 scenes available
- 3.8 PB of data accessed
- Over 560 million hits from 167 countries
- 3.7 million average requests per day
- 25 TB average data transferred per day

Amazon Simple Storage Service (Amazon S3) provides developers and IT teams with secure, durable, highly-scalable object storage. Amazon S3 is storage for the Internet. It is designed to make web-scale computing easier for developers. It has a simple web services interface that users can use to store and retrieve any amount of data, at any time, from anywhere on the web. It gives any developer access to the same highly scalable, reliable, fast, inexpensive data storage infrastructure that Amazon uses to run its own global network of web sites. The service aims at maximizing benefits of scale and passing those benefits on to developers. There are not any commercial restrictions on the use of data received from the USGS EROS Centre or NASA's Land Processes Distributed Active Archive Center (LP DAAC).

AWS has positioned itself as an intermediate that fosters Landsat data utilization and enables the market to grow. Without the Landsat data available on the S3 platform, many users will never have used this type of data. In this context, USGS has acted as a market enabler when they have developed a tailored access for large scale users, indirectly enabling the Landsat data to be used by non-technical actors. **Having large companies such as AWS, Google or Microsoft using Landsat data to create business around it is not perceived as a threat by USGS.**

At the opposite, it is an opportunity for them to let third parties dealing with private end users, allowing the US agency to focus more on better respond to scientific and governmental users' communities. These large ICT companies are not willing to provide directly any processing activities; their core business is providing data, not being an EO-data expert. These actors are mostly a new player on the EO downstream market that enable the market to grow and to be connected with a multitude of other data sources to implement an innovative virtual ecosystem around Big Data.

The Copernicus programme

The Copernicus generic data access & distribution infrastructure

The Copernicus data access and distribution infrastructure is based on the ESA Earth observation missions implemented over the last 20 years. The network of data repositories is distributed all over Europe and shared with national space agencies, national agencies and some commercial missions. The Copernicus programme was developed using the **Processing and Archiving Centres (PAC),** the ESA specific ground segment with fast delivery capability able to offer EO data in less than 3 hours after acquisition.

Reusing the data exploitation chain explained in section "Data access and data distribution on the EO downstream market" and applying it to the Copernicus programme, Sentinels data are downlinked to ground stations all over the world that are then centralized in ESOC ground station in Germany, where automatic processing transforms Sentinels raw data into level 0 information. Then, the ESA European Space Operation Centre (ESOC) is sending the data to the different PAC centres all over Europe depending on their previous experience with EO missions (optical, radar, etc.). These centres are commonly called Sentinel **Payload Data Ground Segment (PDGS)**. They are then in charge of **all processing activities to higher level than 0** (based on the mission design), the **production of metadata, the storage of such data and their on-line availability for authorised download**. To ensure the long-term data access of the Copernicus programme, all the data are at least stored in two different centres. ESA European Space Research Institute (ESRIN) in Italy is then in charge of data flow management and user management. The same infrastructure is used to host the contributing missions' data of the Copernicus programme.

Access to Sentinels data is operated by ESA through the hub servers: the Scientific Data Hub and the Collaborative Data Hub. Users access rolling archives through a web-based interface where users can search for the Sentinels data required. The scientific data Hub is the generic open and free data access interface where all the Sentinels products are made available through three different APIs: the Scientific Hub, the API hub and S2-PreOpsHub. The collaborative data Hub corresponds to the access to the collaborative ground segment of a given country, providing specific data for regional and national interest in near-real time (less than 3 hours), together with specific tools and applications. Finally, contributing missions' data can be accessed through the coordinated data access system. No data related to the use of contributing missions are published. The chart below summarises at a high level the data access and distribution infrastructure of the Sentinels products.

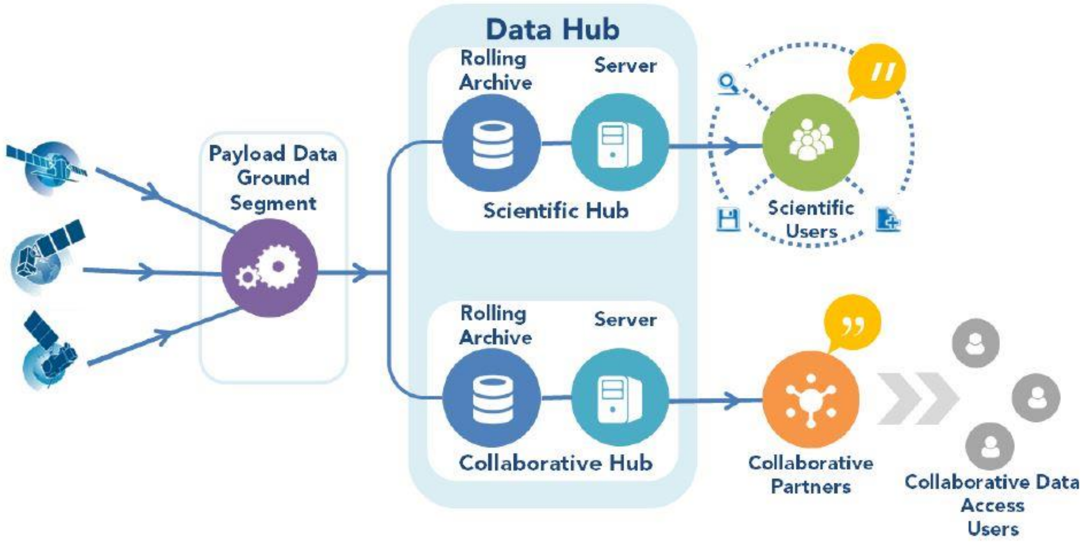


Figure 37 - Copernicus data access & distribution (Sources: ESA, 2015)[72]

Compared to the Landsat programme, the Copernicus programme only offers a regular channel to access and download Sentinels raw data or products on a one-by-one scene basis. Copernicus is not providing a dedicated access for large volume users with higher downloading rate. However, such types of actors are downloading continuously Sentinels 1 and 2 products and make them freely available on their own infrastructure. Companies like Amazon Web Services or Google Cloud already offer dedicated buckets of Sentinels data on their IaaS cloud platform, enabling US companies such as Esri or Planet Labs, but also European companies such as Sinergise to offer Sentinels products on their APIs.

Statistics of the Copernicus data access and distribution infrastructure

The following statistics are derived from the Sentinels Data Access Annual Report developed by Serco and ESA in 2015. This report covers only the period 03/10/2014 to 30/11/2015. No more recent statistics are publicly available. Figure 38 gives an overview of the Copernicus users-declared data usage per type of actors and thematic areas.

[72] *ESA, 2015. Sentinels Data Access Annual Report. Issue 1, Rev. 1. Prepared by SERCO for the European Space Agency.*

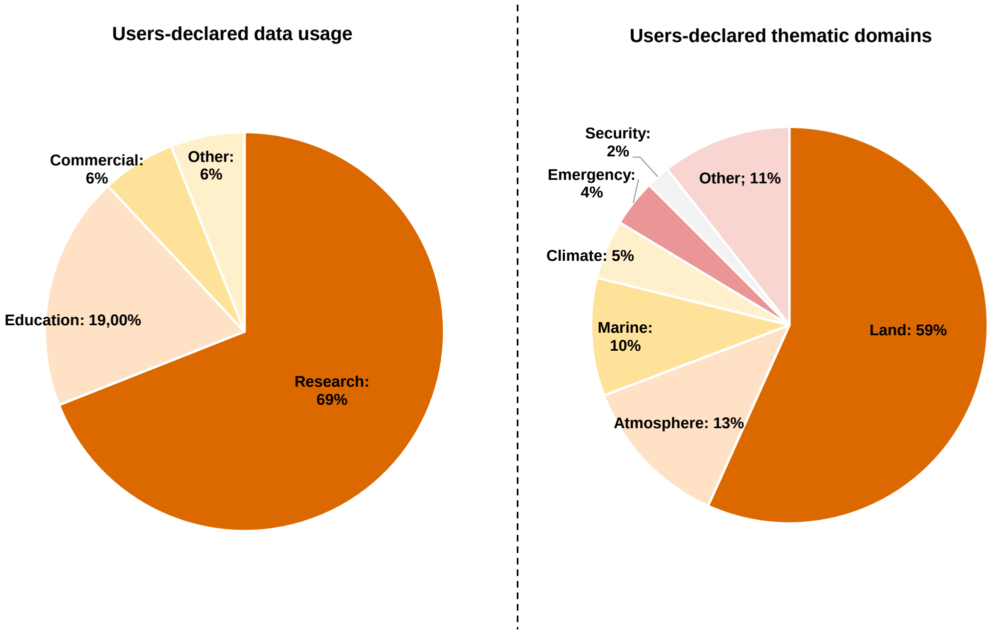


Figure 38 - Copernicus users-declared data usage per type of actors and thematic areas over the period 03/10/2014 to 30/11/2015 (Sources: ESA, 2015)

The first observation is the split of users where scientific usage account for 88% and commercial only 6%; the Landsat programme accounts respectively for 76% and 15%. Almost 60% of the users are focusing on the land monitoring thematic, followed by Atmosphere (13%) and Marine (10%). These figures have to be linked to the period under scrutiny finishing in November 2015, while Sentinel-2-A was launched in June 2015. Most of the statics in this report are based on the usage of Sentinel-1 products.

Up to November, 30 2015, more than 2 750 000 products were downloaded on the Scientific Hub and around 240 000 on the Collaborative Hub. These figures are encouraging since the Copernicus access infrastructure was open in 2014, but there are still very small compared to the Landsat programme.

A need for a unified access platform

The current Scientific Hub platform offers a good access to discover metadata. The European Commission has recently performed a Copernicus users' survey where 46% of users **stress the clarity of metadata**[73]. However, respondents of the survey mostly expressed difficulties regarding access and downloading of Copernicus products. 44% of respondents have raised the fact they were **facing recurrent issues to access Copernicus data and products**. Respondents are complaining about a slow and unreliable downloading rate for Copernicus data, together with a file format overly complex. When asked how to increase the use of Copernicus data, 53% of the respondents have pinpointed **the need for a stronger downloading speed**. Stakeholder consultation has highlighted the fact that some technical parameters of the Scientific Hub Data infrastructure can be improved to stimulate the value created through the free and open data policy of the Copernicus programme. When compared to Landsat 8 parameters for example, the USGS portal is way more predictable for near-real time data access. Timeliness is key for a large range of applications, notably the ones using Sentinel-2 products. These parameters need to be improved in the future to insure predictability for commercial services and security services relying on Sentinels products, and to be at least on the same level than the USGS portal.

When asked about how to facilitate the use and dissemination of Copernicus products, **58% of the respondents argue the first priority related to access and distribution for the Copernicus programme is to establish a unified portal for all Copernicus products and data**. This observation is very important and completely in accordance to what the current study has noted discussing with more than 140 international stakeholders including intermediate EO users, end users and ICT companies. The access is even more complex for all non-EO experts having interests in Sentinels products. The vast majority of end users interviewed in the 8 sectoral uses under scrutiny in this study were not able to directly use Copernicus products. Their main issue was the

73 European Union, 2016. European Union survey analysis. "Boosting the growth of European EO companies". June, 2016.

complexity, as non EO-expert, to access the Sentinels products of interest through the Scientific Data Hub. The access is quite technical requiring for example for Sentinel-1 specific information on the product type, polarization required, sensor mode and relative orbit number; most non-EO experts does not have the knowledge to require the correct data. The aim of an open data programme is to reach as much users as possible. The pool of non-expert users is much larger than EO experts, so the potential value derived from the use of Copernicus products by non-EO experts is also much larger than the one derived from intermediate users. As an example, the exploration O&G value-chain presented in the next section stresses the fact that most of the enabled revenues by the Copernicus products were found in the end user category, not in the intermediate users – please refer to the section O&G for more details.
Another example is the use of the Copernicus data. In November 2015, the Copernicus programme only had 15,000 users registered, compared to 44,731 registered users in 2012 (no more recent USGS survey available) for the Landsat programme. Registration, at the opposite of the Copernicus programme, is not mandatory to access to Landsat data which may involve the possibility of a much larger number of users. Having a simplified and unified access for all Copernicus products should stimulate the number of users of the Copernicus data infrastructure.

There is a **strong need for a simplification and mutualisation of the Copernicus distribution infrastructure** to foster the Copernicus data dissemination through one or several interfaces. These **APIs should be able to unify on the same "one-stop shop" per domain of interest** all the existing access to Sentinels products (Scientific Hub, API Hub, S-2 PreOpsHub, Collaborative Ground Segments, Copernicus core services), in-situ data and contributing missions data directly on the cloud, and **using the last developments in semantic web**, notably natural language processing[74] **to foster the dissemination of Copernicus products within non-EO expert communities**. Such access requires a dedicated IaaS cloud service for all Copernicus products produced in both near-real time access and long-term data access. Strong interoperability, using widely used standards, is then required to be able to connect the dots between the Copernicus existing infrastructure and all the other potential web-based portals of interest for European EO data users such as the USGS one but also the private initiatives such AWS S3, Microsoft Azure, Google Cloud or The Geospatial Big Data platform of DG. The aim of such an initiative is to make sure the Copernicus programme supports and benefits from the current platform paradigm going on the EO downstream market. The Copernicus programme has to develop the proper infrastructure and a unified access, based on one or several interfaces, to be connected to the new virtual EO downstream and GIS inter-connected ecosystem.

The new approach recently developed by ESA and the six Thematic Exploitation Platforms (TEP) are also a potential way forward for the Copernicus programme. TEPs correspond to virtual workplaces providing a user community interested in a common Earth Science topic with a very fast access to large volume of data, computing resources, processing software and general platform capabilities. TEP are based on a pay-per-use business model and they offer in the same virtual space[75]:

- EO and in-situ data;
- Computing resources, hosted processing and scalable network (IaaS cloud service);
- An environment where users can integrate data, test and run data, developing their own tools or application using IDL or Python for example. Users can also directly access on the cloud data mining and visualisation tools, together with different resource utilisation tools. (PaaS cloud service);
- An access to the most advanced processing tools or applications freely and/or commercially available (SaaS cloud service).

TEPs try to make the most possible use of open source software, tools and applications free-of-charge. ESA platforms also implements specific standards to ensure interoperability. The TEPs are public-private partnerships involving universities, ICT companies and intermediate users with common interest. Currently, six thematic platforms have been launched by ESA, starting in 2014 and up to 2017:

- TEP Geo-hazard
- TEP Coastal
- TEP Forestry
- TEP Hydrology

74 As already stated in the previous section about Big Data:
Natural Language Processing is a discipline in computer science related to computational linguistics, machine-learning and artificial intelligence. The aim is to create interactions between computers and human language to facilitate access to data.
[75] ESA website, consulted June 6 2016
Link: https://earth.esa.int/web/guest/-/esa-selects-themes-for-eo-thematic-exploitation-platforms

- TEP Polar
- TEP Urban

With a unified access and centralized data base easily accessible for all related Copernicus products and services as discussed in the beginning of this section, having dedicated APIs by thematic can bring an important value for very specific communities sharing the same interests and problematics. A multitude of thematic platforms already exist in Europe and throughout the world for very specific communities. The TEP approach is very interesting for very specific areas but ESA needs to insure no overlaps exist between platforms to avoid redundancy and duplication of sources of information. Economical and technical viability assessments of such initiatives have to be performed by the EC and/or ESA to understand if this the best way to go forward for the Copernicus data dissemination. Other potential solutions, notably the one based on private initiatives, may also be possible.

Focus: Earth Observation 2.0 companies

Key specificities

Earth Observation (EO) 2.0 is term that gathers NewSpace industry players operating in the Earth Observation business. The NewSpace approach to Earth Observation brought a new perspective to the EO downstream market, and has proposed novel business models that might disrupt the industry. EO 2.0 players include the new start-ups in North America entering the imagery market with a vertically-integrated structure (from satellite-manufacturing to products and services provision). These companies are currently undertaking ambitious plans to launch large constellations of nano/micro-satellites in Low Earth Orbit (LEO).

- **The EO 2.0 companies refer to the New Space ventures on the imagery market emerging mostly in North America. These new integrated companies rely on large constellation of small satellites offering novel business proposition and disruptive services on a conventional and mature imagery market.**
- **EO 2.0 companies have a very high capacity to attract investment, more than all the other entities on the EO downstream market. This capacity attracts the interest of the business press, contributing to a marketing effect for such companies.**
- **New Space imagery companies rely on strong cloud expertise and computing power, together with high software development capacity. These 3 factors together give EO 2.0 companies a competitive advantage compared to more conventional EO downstream companies but also offer them the opportunity to easily turn to the very attractive GIS market, especially to the cloud GIS market.**
- **EO 2.0 endeavours are generally kickstarted by private investment, especially from venture capitalists (VCs), which leads to a strong pressure to deliver value. EO 2.0 companies' growth strategies are intrinsically linked to the goals of VCs to increase the value of these ventures. Main growth strategies of EO 2.0 were mapped and analysed here.**
- **A specific attention was given to the reaction of the competition on the EO downstream market, with a particular focus on the leader of market Digital Globe and Airbus DS. The public declaration in one hand and the actions taken on another hand are analysed to highlight the perception of the EO downstream market related to these new ventures.**

Scope/Boundary

The analysis here focuses on NewSpace companies (see the next section for a definition of NewSpace) involved in the current or prospective provision of Earth Observation services in quasi-static imaging, video streaming and meteo. The analysis looked at EO2.0 players worldwide, with a deep dive on the US market (the regional market with the highest volume of NewSpace investments).

Taxonomy and Definitions

New Space

Privately funded space development activities have been historically confined to the downstream in most domains, with the possible exception of satellite communication. In the past decades, commercial space endeavours detached by large space agencies' funding started to appear in the upstream side of the space value chain in the U.S. in several domains. This new commercial space industry is identified with the moniker **NewSpace.** NewSpace is characterized by the pursuit of space technology and systems development using (mainly) private capital, and leveraging approaches that differ significantly from those taken by NASA (and other space agencies) and the mainstream aerospace industry. These approaches include:

- Design-to-Cost aimed at reducing development and operational (recurrent) costs, pursued either by exploiting innovative (non-proven) tech that can lead to cost savings (often spun in from non-space sectors), or by using cheap commercial off the shelf technologies in an innovative way

- Incremental development, entailing the pursuit of intermediate simple goals to achieve profitability with intermediate products/service to fund further development or to prove a concept (e.g. Falcon 1 to Falcon 9, PlanetLabs Cubesats)

The new commercial space industry originated and gained critical mass within the space transportation domain: following the fulfilment of the Ansari X-Prize by the SpaceShipOne, a commercial suborbital spaceflight industry came into definition. Commercial space in the U.S. encompasses now the full spectrum of space domains with the notable, understandable exception of satellite navigation.

Earth Observation 2.0

Earth Observation 2.0 indicates the NewSpace ventures in the space imaging business: several business propositions based on the use of low-cost nano/micro-satellites systems from LEO have appeared in the last decade. The development hub for nano/micro-satellite based commercial companies in the U.S. is represented by the Silicon Valley itself: the New Economy mindset, and the plethora of new services/IT applications being developed in the area turned out to pair well with the possibilities of new low-cost satellite services.

Over the last 5 years, technological and business newspapers have relayed a large quantity of information related to new EO start-ups, the launches of cube satellites or announcement of small satellites LEO constellations. The EO 2.0 entered the **Space-Based** data provision market **with novel business propositions and with disruptive services and products, that, although yet to reach market maturity or yet to prove business viability, created a stir in the conventional Earth Observation market.**

The new entrants capitalize on new technologies or, more often, on novel business approaches exploiting**, in NewSpace fashion,** cheaper off-the-shelf 'good enough' technologies. These companies are vertically integrated, which means they all have in-house capabilities to manufacture satellites, operate them and distribute the data and services related to it.

Rationale for assessing the state of the Earth Observation 2.0 industry and its implications on the EO downstream market

The choice of EO 2.0 companies as a case study to illustrate the new trends and tendency raised in the data access and distribution chapter related to the platform paradigm. This choice was also made to better highlight and understand the novel business models and potential new markets enabled by the emergence of these private ventures. The literature review showed a lack of pre-existent market characterisation focused on EO 2.0 actors, with the main sources of information being the business and technology journal articles, mostly from Bloomberg or specialized space journals (reporting on new LEO constellations' plans and on private investments in the space imaging business). Therefore, the data used for this assessment comes mainly from primary research, conducted through direct consultation with EO 2.0 players in the U.S. and with experts from the incumbent companies and institutions.

The innovation brought upon by EO2.0 players impacts mostly the commercial space-data market. However, as we will see in the remainder of this section, the integration of the new data offering from these players into the new platform paradigm for data distribution creates interesting market possibilities for the combined use of open data like Copernicus/Landsat and novel EO2.0 data sources.

The main characterizing features of EO2.0 companies are:

- Leverage on nano/micro satellites constellation with lower lifecycle
- Vertical integration

Novel, subscription platform-based go-to-market approaches for data and services

- **Strong IT literacy**
- Strong backing from VC and private investors

The remainder of this section will briefly describe the main characterizing feature of this new industry, highlighting impacts and implications for an open data programme like Copernicus.

A novel approach to asset development, deployment and operations

EO 2.0 initiatives rely on **high volume nano/micro-**satellites **as opposed to large, dedicated spacecraft as for incumbent mainstream EO companies**. The **main data producing asset are** constellations of cubesats or nano**/** micro satellites**, produced and launched** at a small fraction of regular EO satellites prices.

Nano/micro-satellites are also extremely quicker to build, and, while the need for dedicated launch services for such systems will eventually be a bottleneck (as current systems cannot ensure the launch frequency and the flexibility that will be required once the constellations come into full deployment), in principles such satellites are cheaper and easier to deploy in bunches. This implies lower reaction times and higher flexibility in a market that has been historically characterized by the long term exploitation of a small number of expensive assets.
To put things in perspective, as an example DigitalGlobe satellites WorldView-3 and WorldView-4 cost around USD 750 million each (including insurance and launch)[76] while Skysat-1, the first satellite sent by Skybox (now Terra Bella) – a mini-fridge sized satellite – costs less than USD 50 million (including insurance and launch).[77] Four years are required to build one WorldView-like satellite whereas a Skysat-like satellite can be build and ready to be launched in a few months[76].

It is easy then to understand that EO2.0 companies exhibit much lower financial risk associated to asset loss, since they are much less impacted by the loss of a satellite than traditional EO data providers on account of the possibility to replace it quickly and a relatively low cost.

The mega-constellations nano/micro-satellites in LEO allow an efficient monitoring of the entirety of the Earth surface with a high revisit time, up to one hour or even few minutes in certain planned constellations.

Several business propositions based on the use of these low-cost nano/micro-satellites systems from LEO have appeared in the last few years (e.g. PlanetLabs, Terra Bella – formerly Skybox Imaging Google –, UrtheCast, Spire, etc.). The core differentiating factor of these companies compared to EO incumbents is their tasking capacity – the tasking capacity refers to the capacity to monitor in real-time a given geographic area at a given time – which is much higher compared to conventional EO data providers. Large constellations of satellites in LEO enable to increase significantly the revisiting time in one hand but also their capacity to provide tasking activities for a large number of users at the same time. This capacity, which is not currently offered by incumbents using a low number of large satellites, will potentially enable a near-real time monitoring with medium, high and very high spatial resolution at low cost. The cost reduction on imagery is expected to stimulate the demand and create a new market of products based on this unique capacity.

EO2.0 also relies on an agile approach using on-board upgradable processing capacity together with strong ICT and software capacities when it comes to data processing. This new wave of companies bring an innovative way to tackle the EO downstream market, generating innovation, as it often happens, at the interface of different disciplines[78], in this case satellite technologies and ITC. EO 2.0 players, at different levels in each different company, bring together space technologies with cutting-edge information and communications technologies and high IT literacy of their staff, impacting positively operations (bringing for example quick satellite software upgrades from the ground) and exploitation (with end-to-end application developments).

For EO 2.0 actors, the added value is mostly derived from scalable computing and not from the satellite itself, which is seen as a mere data-generating sensor.[79] This novel approach has profound implications in the way the earth observation business has been seen so far, bringing the space sector closer to the agile mind-set of the ICT and new economy.

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[76] *De Selding, P.B. "DigitalGlobe Chief Sees No Competitive Threat from Earth Imagery Startups". Space news. May, 21 2015.*
Link: http://spacenews.com/digitalglobe-chief-sees-no-competitive-threat-from-earth-imagery-startups/
[77] *Samuels, D. "Inside a start-up's plan to turn a swarm of DIY satellites into an all-seeing eye". Wired. June, 18 2013. Link: http://www.wired.com/2013/06/startup-skybox/*
[78] *Koestler, 1964. The Act of Creation. Penguin Books. New-York, USA.*
[79] *Skybox Imaging website. Consulted November, 18 2015. Link: http://www.skyboximaging.com/company#about*

Private capital as the main start-up enabler, dictating governance and companies' evolution

Figure 39 summarises investments made in commercial space the period 2000-2015 globally. On the overall period, more than USD 13,250 M were invested in start-up space ventures, specifically with 38% in debt financing and 22% in venture capital.[80]

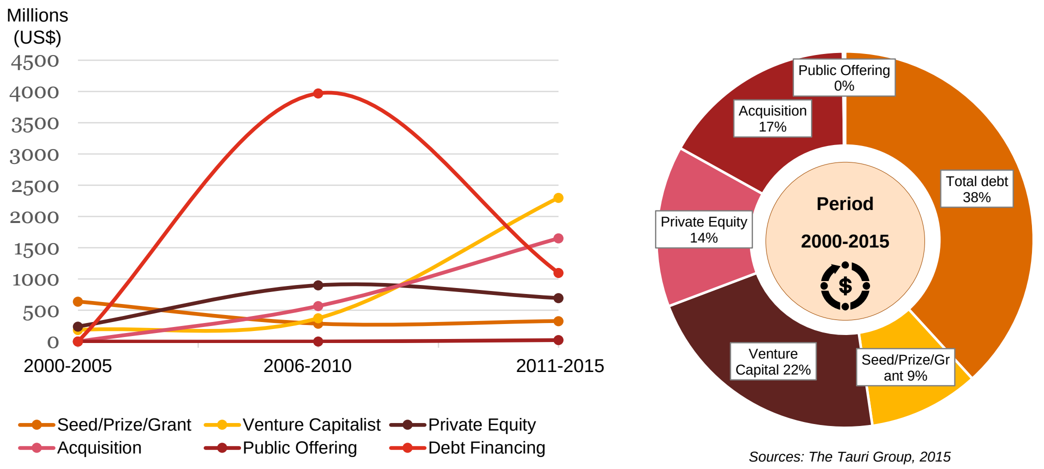

Figure 39 - Investments made in commercial space over the period 2000-2015 worldwide (Sources: PwC-Strategy& , based on The Tauri Group, 2016)

Note that debt financing was very high over the period 2006-2010 because of the financial crisis in 2008. More venture capital was invested over the last period (2011-2015) than all the venture capital invested before. 66% of these investors are in the US (with a large majority in California; 30% overall) and the 34% remaining are split among 25 countries from Americas, Europe, Middle East, and Asia/Africa/Oceania.

EO 2.0 companies have raised awareness by being able to attract venture capitalists:

- Skybox Imaging has received USD 91 million in private capital, before being bought by Google for USD 500 million[81].
- Since its creation in 2010, Planet Labs has received USD 183 million in cumulative private investment.[82] This capital has enabled them to buy Black Bridge in July 2015 for an undisclosed amount of money.[83]
- Spire Global has raised USD 25 million in venture capital in July 2014.[84]
- Urthecast has initially raised USD 55 million on the market to develop its cameras and another USD 100 million recently to acquire Deimos Imaging, the Earth Observation branch of Elecnor-Deimos.[85]

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[80] *The Tauri Group, 2016. Start-up Space. Alexandria, USA.*
[81] *Burns, M. "Skybox Imaging Raises $70M To Launch Two High-Res Imaging Microsatellites". TechCrunch. April 17, 2012. Link : http://techcrunch.com/2012/04/17/skybox-imaging-closes-70m-in-series-c-funding-with-immediate-plans-to-lauch-two-high-res-imaging-microsatellites/*
Source: Womack, B. "Google buying satellite company Skybox for $500 million in cash". Bloomberg. June, 11 2014 Link: http://www.bloomberg.com/news/articles/2014-06-10/google-buying-satellite-company-skybox-imaging-for-500-million
[82] Buhr, S. "Planet Labs Rockets To $118 Million In Series C Funding To Cover The Earth In Tiny Satellites". TechCrunch. April, 13 2015.
[83] *Foust, J. Planet Labs Buying BlackBridge and its RapidEye Constellation. Space News. July, 15 2015. Link: http://spacenews.com/planet-labs-buying-blackbridge-and-its-rapideye-constellation/*
[84] *Spire Global website. Consulted December, 5 2015. Link : https://spire.com/insights/news/spire-funding-annoucement/*
[85] *CBC Canada. UrtheCast cameras successfully installed on ISS, CEO says. CBC Canada. January, 28 2014. Link: http://www.cbc.ca/news/canada/british-columbia/urthecast-cameras-successfully-installed-on-iss-ceo-says-1.2512185*
Kearns, J and De Vynck, G. "UtheCast Acquires Deimos to Double its Space-Imaging Capability". Bloomberg. June, 22 2015. Link: http://www.bloomberg.com/news/articles/2015-06-22/urthecast-acquires-deimos-to-double-its-space-imaging-capability

The capacity to attract investments for inorganic growth via acquisition of incumbent EO companies is a game-changer for the industry. With the acquisition of Deimos Imaging by UrtheCast and BlackBridge by PlanetLabs, EO2.0 is effectively engaged in the Copernicus programme with a full European presence and an opportunity to influence the future of the Copernicus programme.

Mapping the phenomenon

As with the rest of the NewSpace sector, EO 2.0 raised the awareness level of the generalist investment community, and, to a certain extent, of the general public, towards space: the generalist and business press (Bloomberg, Times, Wall Street Journal, etc.) dedicated frontline columns to these new private ventures, further contributing to attracting the interest of the non-space business community. Some initiatives, such as Planet Labs, Skybox (now Terra Bella) and to a lesser extent UrtheCast have received an important public attention over the last years while companies such as Spire and Black Sky Global are only known within the EO community.
Even if all these initiatives always propose a differentiation from the competition, some patterns can be found within the type of system (satellites) used, the type of ICT infrastructure used, the business models or the way to access the market. Table 11 gives a non-exhaustive overview of the 5 main EO 2.0 initiatives.

	System	Product(s)	Business model	IT infrastructure	Access to market
Terra Bella	• Constellation of small satellites	• GIS	• To Be Determined	• Own API	• To Be Determined
PLANET LABS	• Constellation of micro-satellites in LEO • Black Bridge high-resolution satellites	• All areas • Data sales • VAS provider	• Target very high tasking capacity • Very low revisiting time	• Own API	• Distribution through their platform • Traditional VAS provider

urthecast	• 3 cameras (video) on the ISS
	• Constellation of 16 sat. in LEO planned (platform mixing radar & optic)
		• All areas
		• Data sales
			• Offering innovative products
			  • Mixing radar & optic
			  • Video streaming
			• Target low revisiting time
				• Own API	• Distribution through their platform

spire	• 8 satellites in LEO • Constellation of 100 sat. in LEO planned	• Maritime intelligence • Private weather forecast	• Target very low revisiting time (down to 3 min)	• Own API	• Distribution through their platform
BLACKSKY	• Target a constellation of 60 opt. sat. in LEO • Micro satellites orbiting around 450-500km	• All areas • Data sales	• "Pay per picture" business model • Very low revisiting time (up to 70 times/day) • Very high resolution	• Plan to develop web-scale software platform	• Distribution through their platform

Table 11 - Comparison of the different EO 2.0 actors (Sources: expert consultation; PwC-Strategy& analysis)

The new business proposition of EO 2.0 companies rely on the last development in terms of data distribution and access, offering dedicated cloud-based APIs relying on Amazon S3, Microsoft Azure or Google Cloud to host their data. As already mentioned, this new trend surfs on the new platform paradigm and tile approach to offer a higher value-added to their customers and facilitating the access to data for new comers non-EO experts.

Towards the development of a commercial mass-market

EO 2.0 actors target a very low revisiting time and high tasking capabilities thanks to large constellations of small satellites in LEO. This capacity enables the provision of near-real time and less than 24 hours tasking activities at very low cost compared to the traditional EO service provision. This type of tasking enables the customer to receive the data in less than 24 hours with the spatial resolution, timing, type of sensors and specific wavelengths required for a given geographical area. The data is provided raw, pre-processed or processed depending on the user requirements; the price varies a lot depending on the expected outputs and the timing asked.

Beyond the high tasking capacity, EO 2.0 players have already started operating the switch from the pixel market to the tile approach (see the section on EO market characterization and the one on data dissemination for more details on the tile approach), through the use of analytics platforms providing a user-friendly API, tools and algorithms for on-the-cloud processing. This type of platforms is a new channel of distribution for EO downstream players that reduce the time of analysis and delivery, facilitating the use of imagery for non-EO experts. The use of such channels, together with the high tasking capacity of EO 2.0 enables the provision of new business intelligence such as near-real time monitoring of specific areas.

This is expected to lead to a shift in customer demand from VAS and IP to fully-fledged intelligence and consulting solutions. This type of services enables the development of solutions to be applied daily on a tile platform to monitor a livestock of la given resource such as monitoring oyster parks and toxic algae for example.

The traditional EO downstream market has failed in the past to develop a cost-efficient commercial mass-market to respond to specific commercial needs through tailored products and consultancy services. The high revisiting time, high costs and small capacity for near-real time tasking prevents such market to grow. EO 2.0 actors may be able to generate and cater to a demand for near-real time very high resolution data, delivered on a continuous platform for daily monitoring in order to propose tailored business intelligence to customers instead of outputs that require further analysis.

From imagery to geo-information

"As we have engaged with thousands of potential users, we have been struck over and over again by a simple truth. There is an incredible opportunity for geospatial information to transform our ability to meet the economic, societal, and humanitarian challenges of the 21st century, but satellite imagery represents only one part of the puzzle."[86]
Dan Berkenstock, John Fenwick and Ching-Yu Hu, Skybox (now Terra Bella) founders

Global business and societal challenges grow more and more complex and require the integration of a growing number of data sources and parameters to be addressed effectively. EO data are in most of the cases only one component of the solution as required to address end users' needs, among other sources of data. EO 2.0 companies have strong capacities in software development, computing power and powerful cloud capacity. This expertise facilitates the treatment and integration of large volume of data coming from many different sources. These capacities and expertise gives them a comparative advantage compared to conventional EO downstream actors, stimulating and facilitating the switch to the very attractive GIS market. Currently estimated around USD 7,610 million, the worldwide GIS market is expected to reach USD 14,624 million by 2020.[87] (please see the EO market characterization section for further details). Most of the EO 2.0 companies moved from the pure space-based EO downstream market to the GIS one, attracted by the size and the growth rate of this market. Additionally, this market has already set up a digital environment through the development of powerful analytics platform such as the Arc GIS software from Esri. The GIS cloud market is estimated at USD 519 million in 2015 and it is expected to grow up to USD 875.9 million by 2020.[88] GIS customers are already used to this type of platform facilitating the customers' uptake on the GIS cloud market and diminishing the risks for new entrants.

This context contributes to EO 2.0 companies which are early adopters of the tile approach/platform paradigm earlier mentioned. The existence on the web of a multitude of data sources thanks to powerful platforms such as AWS S3, Microsoft Azure or Google Cloud facilitates the development of GIS products and services at low cost for EO 2.0 actors, without being obliged to buy and store large sets of in-situ data. Having powerful computing capability and large constellation of high and very high resolutions data offer a competitive advantage to EO 2.0 actors compared to purely GIS actors such as Esri or Hexagon AB, the two leaders on the GIS cloud market. The high tasking capacity for near-real time monitoring of EO 2.0 firms should also bring a competitive advantage on the GIS market compared to conventional GIS products and services providers.

Even if companies such as Planet Labs and UrtheCast have manifested their interests in the GIS market, only Google has officially switched to this market by re-branding its subsidiary Skybox Imaging by Terra Bella. Terra Bella is now focusing, beyond the imagery, on wide ranges of geospatial data sources and machine learning capabilities. The former-Skybox company has made the choice not to focus on the provision of raw data but rather on the provision of business intelligence for the end users, which confirmed the switch from a pixel approach to a tile one.

Different growth strategies

[86] *Sources: Protalinski, Emil. "Google rebrands Skybox as Terra Bella, will launch 'more than a dozen satellites' over the next few years". VentureBeat Journal, March, 8 2016*
Link: http://venturebeat.com/2016/03/08/google-rebrands-skybox-as-terra-bella-will-launch-more-than-a-dozen-satellites-over-the-next-few-years/
[87] *P&S Market Research, 2016. Published on PR News Wire website, February, 4 2016.*
Link: http://www.prnewswire.com/news-releases/global-geographic-information-system-gis-market-expected-to-grow-at-11-cagr-during-2015---2020-ps-market-research-567650721.html
[88] *Technavio, 2015. Global Cloud GIS Market 2016-2020.*

EO 2.0 companies exhibit similarities in their offer of services, business model and way to deliver products and services. Additionally, most of these start-ups were or are founded by **venture capitalist (VC) investments, something that affects the way those companies are expected to develop**. Indeed, while VC allows the kickstarting of different and innovative activities, it also brings financial constraints for the companies receiving the investment: having VCs in the equity of a firm forces it to grow very quickly. EO 2.0 companies do not escape such a general rule of the investment world and Figure 40 gives an overview of the evolution of bargaining power within a start-up, between the individuals that bring the idea (founders) and the investors.

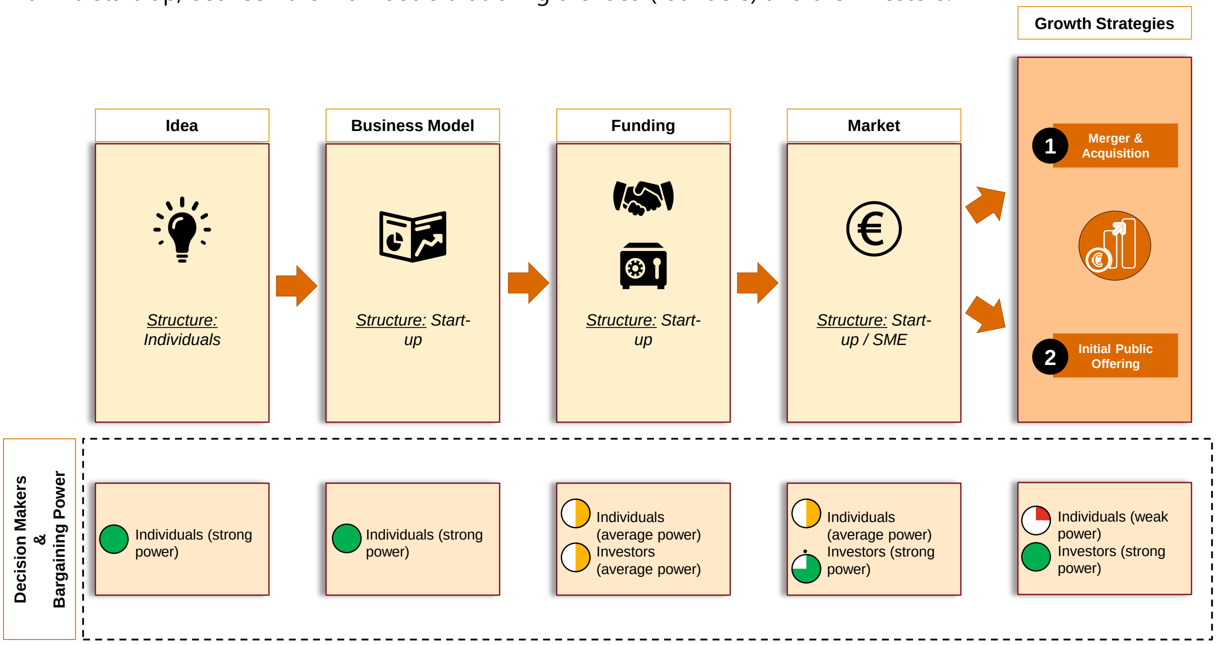

Figure 40 - Bargaining power along the development of a start-up (Source: PwC-Strategy& analysis)

To bring an idea to the market, founders need to access private capital(s) to be able to fund their activities. VCs are nowadays the main type of investors in EO 2.0 ventures, as pointed out in the previous subsections. Figure 40 shows clearly the evolution of the bargaining power of investors versus founders. VCs bargaining power becomes stronger and stronger, while founders' bargaining power diminishes, as the start-up enters the market and gets into a growth cycle.

Once the VCs have invested in a private venture, their goal is to increase the value of their capital on the market; this statement strongly impacts the start-up operation and strategy because it then needs to quickly develop revenue streams or attract new investors. The ultimate outcome is for VCs to have potential exit opportunities, since VCs are mid-term investors, and the average estimated time-to-exit, through Initial Public Offering (IPO) or Merger & Acquisition (M&A) –the main two exit strategies –, for such investors is estimated by CB Insights Research at around 5 years.[89] Time-to-exit diverges from one industry to another: internet and mobile companies have an average time-to-exit of about 3 years (both via M&G and IPO) whereas technologies companies have an average time-to-exit of 4.5 years through M&A and 7 years through IPO.[89]

EO 2.0 actors on the market for several years such as Skybox, Planet Labs and UrtheCast[90] had to use these strategies to offer a potential exit to their early investors. UrtheCast was founded in 2010 and it went public through an IPO in 2013 on the Toronto Stock Exchange. Then, the three companies have used M&A strategies to offer valuation options to their VCs.

Two different approaches were used by EO 2.0 companies, being acquired and acquire:

- Skybox was acquired by Google and renamed Skybox Imaging and then Terra Bella. This operation has raised the value of Skybox up to USD 500 million in 2014, for an initial VC investment of USD 90 million.[91]

[89] *CB Insights Research. "It's Definitely a Marathon – Venture – Backed Tech IPOs Take Seven Years from First Financing". November, 7 2013.*
Link: http://www.cbinsights.com/blog/venture-capital-exit-timeframe-tech/
[90] *Spire and Black Sky Global are recent initiatives so they have not been on the market for long enough to use such growth strategies.*
[91] *De Selding, P. B. "Skybox Gets Creative To Raise Capital from Wary Investors". Space News. March, 26 2013.*
Link: http://spacenews.com/130326skybox-gets-creative-to-raise-capital-from-wary-investors/

As an additional interesting example, the Big Data start-up The Climate Corporation was bought by Monsanto USD 1.1 billion in 2013 for an initial VC investment of USD 108.8 million.[92] This strategy should be limited in the future since few companies have the capacity and the interest to invest hundreds of millions in an imagery start-up.

The second M&A strategy used by EO 2.0 is the acquisition model. This strategy relies on the acquisition of traditional EO downstream actors with already significant presence on the pixel market. Such strategy allows the companies to secure some stream of revenues, giving time for the start-up to develop its own stream of revenue related to the constellations of satellites or video stream cameras. PlanetLabs has bought one of the EO downstream leader BlackBridge, with its constellation of five satellites and an archives of six billion square kilometres of imagery, in July 2015 for an undisclosed amount of money.[93] Over the same period, UrtheCast has bought Deimos Imaging, and its two-Deimos satellites (medium and very-high spatial resolution) for EUR 74.2 million (USD 84.2 million).[94] UrtheCast being public, this new acquisition made the stock growing by 28% in two on the Toronto Stock Exchange.[95]

The exit-strategies presented here illustrate the strong power of investors over the EO 2.0 actors. Companies like Planet Labs and UrtheCast have succeeded in their take-off phase being able to satisfy their early investors, and they are now attracting new ones using other funding mechanisms such as regular debts (at least in the case of UrtheCast) now they have demonstrated some solid streams of revenues. However, it is important to always keep in mind the financial pressure such start-ups have compared to traditional EO downstream actors. In fact, VCs have no real interest in the long-term economic sustainability of these companies and they can always withdraw their investment to invest somewhere else. VCs are actually defined by the finance and economy reference website Investopedia as actors that "*are willing to invest in such companies (start-up ventures) because they can earn a massive return on their investments if these companies are a success. Venture capitalists also experience major losses when their picks fail, but these investors are typically wealthy enough that they can afford to take the risks associated with funding young, unproven companies that appear to have a great idea and a great management team.*"[96] Relying on VCs gives EO 2.0 actors access to very important financial resources but it also brings the permanent risk of exit if such actors find more lucrative opportunities. On another hand, a company such as Terra Bella does not have the same risks since they did not received funding from VCs but it was bought by Google. In this sense, the firm is now free from investors and integrated in a larger data strategy – the one of Google – that enable the company to develop long-term strategic plan, switching from the imagery to the GIS market as already mentioned.

Reaction of the competition

A wide consultation with incumbents in the EO downstream market (a pool of companies that included the whole range of player in the market from small VAS providers focusing on niches to very large EO downstream leaders) has shown a general wait-and-see attitude from the traditional EO industry vis-à-vis EO 2.0. Such an attitude is mainly propelled by the fact that the business model for the majority of EO2.0 ventures is, at the state, unproven, with revenues from operations still not there (mostly due to the yet embryonic state of the EO2.0 infrastructures). In fact, most of the operational revenues for Planet Labs and UrtheCast, are at the state attributable to the companies they acquired, respectively Black Bridge and Deimos Imaging (no reliable information on the revenues of Skybox/Terra Bella exists, and commercial plans on the company on Google's side are as of yet unknown). The

[92] *Crunchbase, Investment website. Consulted May, 25 2016.*
Link: https://www.crunchbase.com/organization/the-climate-corporation#/entity

[93] *Foust, J. Planet Labs Buying BlackBridge and its RapidEye Constellation. Space News. July, 15 2015. Link: http://spacenews.com/planet-labs-buying-blackbridge-and-its-rapideye-constellation/*
Kearns, J and De Vynck, G. "Planet Labs Buys BlackBridge Satellite Unit to Expand Fleet". Bloomberg. July, 15 2015. Link: http://www.bloomberg.com/news/articles/2015-07-15/planet-labs-buys-blackbridge-s-satellite-unit-to-expand-fleet

[94] *Kearns, J and De Vynck, G. "UtheCast Acquires Deimos to Double its Space-Imaging Capability". Bloomberg. June, 22 2015. Link: http://www.bloomberg.com/news/articles/2015-06-22/urthecast-acquires-deimos-to-double-its-space-imaging-capability*

[95] *Kearns, J. and De Vynck, G. "UrtheCast Acquires Deimos to Double its Space-Imaging Capability". Bloomberg. June, 22 2015.*
Link: http://www.bloomberg.com/news/articles/2015-06-22/urthecast-acquires-deimos-to-double-its-space-imaging-capability

[96] *Investopedia website. Consulted May, 25 2016.*
Link: http://www.investopedia.com/terms/v/venturecapitalist.asp

lack of revenues streams from EO mega-constellations is being highlighted by business journals[97], with fears of speculation around imagery start-ups to lead to a speculative bubble.

Digital Globe

Digital Globe do not perceive EO 2.0 companies as a threat as stated by Jeffrey R. Tarr, Digital Globe Chief Executive. [98] In fact, they highlight the speculation behind those imagery start-ups that were successful at attracting VCs without being able to demonstrate clear streams of revenues derived from their activities. DG has a very strong presence on the imagery and GIS market, especially among Defence & Security clients, and it offers much higher quality of data, notably being able to provide optical data up to 0.3 meter in spatial resolution for commercial customers – this is the highest resolution available worldwide for commercial users. DG is interested in developing partnerships with such companies in a near-future for specific projects, especially to capitalize on their very low revisiting time[99]

However, DG has declared early 2016 a new joint-venture with the government of Saudi Arabia. They plan to develop a fleet of six small optical very-high resolution satellites to be launched between 2018 and 2019 and that will be operated by Digital Globe. 50% of the capacity over Saudi Arabia and surrounding areas will be owned by the Saudi Arabia nationally-owned King Abdulaziz City for Science and Technology (KACST). The 50 % remaining over this very specific area and 100% of the rights for the rest of the world will be owned by DG.[100] Such an initiative enables DG to increase its refresh rate of very-high resolution optical data to expand the catalogue of its Geospatial Big Data platform.[100] This new plan can also be seen as a reaction to new competitors coming from large constellations of small satellites providing imagery with very low revisiting time. This willingness to invest in smaller and cheaper satellites to provide a better temporal resolution on their API seems to show a different perception from DG's strategic management.

Airbus Defence & Space (DS)[101]

The case of Airbus DS is quite different. First, this company is way bigger than DG and their activities touch all parts of the industrial supply-chain (upstream, midstream and downstream) in mostly all existing space fields, way more than the EO field. However, EO 2.0 actors are perceived as real threats together with other New Space companies such as Space X or Blue Origin and specific strategies were designed by Airbus DS to face them.

To counter these potential threats, Airbus DS has very recently created two new companies located in the Silicon Valley. These two companies, one R&D company and one venture capitalist company, were developed to respond to two new challenges: the digitalization of the economy – to get the mind-set – and the innovator dilemma – how to stay at the forefront of the technology. The goal of developing a Silicon Valley antenna is to be able to go quickly to the market (fast on the market), at the opposite of a big structure such as Airbus. It is also a way to respond to the arrival of EO 2.0 actors and web giants and New Space actors such as Google, Facebook or Space X.

The first company "A^3" is a new development and it is affiliated to Airbus DS US[102]. The aim of such initiative is to scan and map the new developments and expertise available in this very innovative area of the globe. New developments are then transferred to Airbus innovation centres to be incorporated in Airbus D&S' offer of

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[97] *De Selding, P.B. "DigitalGlobe Chief Sees No Competitive Threat from Earth Imagery Startups". Space news. May, 21 2015.*
Link: http://spacenews.com/digitalglobe-chief-sees-no-competitive-threat-from-earth-imagery-startups/
[98] *Source: De Selding, P.B. "DigitalGlobe Chief Sees No Competitive Threat from Earth Imagery Startups". Space news. May, 21 2015.*
Link: http://spacenews.com/digitalglobe-chief-sees-no-competitive-threat-from-earth-imagery-startups/
[99] *Sources: Stakeholder consultation (Digital Globe) and*
De Selding, P.B. "DigitalGlobe Chief Sees No Competitive Threat from Earth Imagery Startups". Space news. May, 21 2015.

[100] *De Selding, P. B. "DigitalGlobe and Saudi government sign joint venture on satellite imaging constellation". Space News. February, 22 2016.*
Link: http://spacenews.com/digitalglobe-and-saudi-government-sign-joint-venture-on-satellite-imaging-constellation/
Meyer, R. "A New 50-Trillion-Pixel Image of Earth, Every Day". The Atlantic. March, 9 2015.
Link: http://www.theatlantic.com/technology/archive/2016/03/terra-bella-planet-labs/472734/
[101] *Source: Stakeholder consultation (Airbus Defense & Space Silicon Valley)*
[102] *Around 95% of the employees of Airbus Defense and Space US are located in Virginia, close by to Washington Dc. A3 is dedicated to scan the Silicon Valley.*

products. The aim of the organization is to rely on the "*bay-area*"[103] ecosystem to prepare future opportunities. The second company, Airbus Venture, was developed in January 2016 and is based in the Silicon Valley, but operating worldwide. This firm is a venture capitalist firm and it is part of the M&A division of Airbus D&S, with an initial budget of USD 150 million.[104] The venture capitalist arm of Airbus D&S has some autonomy and has its own strategy that may not be fully aligned with the other major divisions. The M&A division of Airbus works together with Airbus Venture but the M&A division is taking major control in their strategy whereas Airbus Venture is only doing an investment, without taking any major control.

A certain speculation exists around the massive VC investments over the last 5 years in these private ventures, some experts highlighting a potential speculative bubble around EO 2.0 actors. However, the reaction of DG and Airbus DS, worldwide EO downstream market leaders, shows that EO 2.0 actors are heavily impacting the EO downstream market, and to a certain extent, the GIS market. These actors, together with all the web Giants showing interests in imagery such as the US companies Google, AWS, Apple or Facebook but also the Russian Yandex, the Chinese Baidu or the European Here Maps (Formerly Nokia Maps)[105], are called to play a growing role in the coming years, especially in today's context of digital economy.

[103] *The Bay Area is common name for the bay of San Francisco which includes the Silicon Valley area (Palo Alto, Mountain View.. etc.) but also all the south of San Francisco where many web giants, and other very large US software and IT companies have their headquarters.*

[104] *Vanian, J. "Airbus Venture Capital Arm Lands in Silicon Valley". Fortune. January, 15 2016. Link: http://fortune.com/2016/01/15/airbus-valley-venture-capital/*

[105] *Source: Stakeholder consultation*

Focus: The Landsat programme

Key specificities
The Landsat programme was used as a benchmark for the Copernicus programme with specific reference to the data dissemination strategies put in place, in view of identifying lessons learned for the Copernicus programme. This value-chain analysis has therefore mostly contributed to the Data Dissemination section of this report. The analysis was done on the basis of an in-depth consultation with the US Geological Survey and the industry in Europe and in the US. ➢ **The Landsat programme has the longest archives in the world for medium spatial resolution land remote sensing data (1972-now)** ➢ **The Landsat programme is currently publicly owned but it has also lived a short period of privatization** ➢ **The role of USGS and the type of products offered by the agency brings interesting perspectives for the Copernicus programme, especially related to the questions of public/private boundary, Landsat data access and data dissemination policies** ➢ **The recent developments around Amazon Web Services' Landsat 8 data** dissemination initiative offer interesting statistics, and poses questions on the **role of USGS towards the use of Landsat data by commercial actors**, inside and outside the EO downstream sector ➢ **How USGS has created and develop a creative ecosystem around the Landsat programme and the scientific and public communities of users was also analysed. Interesting lessons learned related to the creation of public knowledge related to EO and how it enables the creation of a commercial market were found.**

Scope of the analysis

The Landsat case study aims at presenting the Landsat programme more in details, with a particular focus on the work done by the "Social and Economic Analysis Branch" of the USGS. They are in charge of Landsat users survey and are developing many case studies on the different use of Landsat imagery, such as agriculture, water management, disaster management or forestry.

Introduction

Landsat is the oldest Earth Observation programme which can be tracked back to the launch of Landsat 1, formerly called the *Earth Resources Technology Satellite*, in July 1972. Landsat is also the world longest archives of medium resolution land remote sensing data. Eight satellites were already launched since 1972 to insure continuity of data provision for Landsat users; the next generation of Landsat spacecraft was planned to be launch in 2023 but the budget for Landsat 9 was approved in February, 9 2016 to be finally launched two years sooner, in 2021.[106] Landsat 7 and 8 were respectively launched in 1999 and 2013 and are currently still operational.

106 Werner, D. and Berger, B."Next Landsat spacecraft would launch two years sooner under White House plan". Space News. February, 10 2016.
Link: http://spacenews.com/next-landsat-spacecraft-would-launch-two-years-sooner-under-white-house-plan/

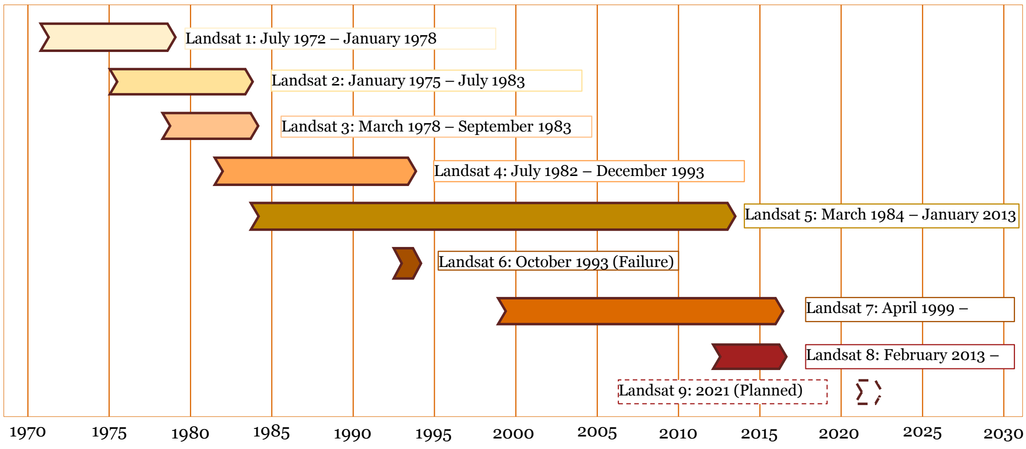

Figure 41 - Landsat missions (Sources: USGS ; Strategy& analysis)

The administration of the Landsat missions has evolved over time. From 1972 to 1979, NASA was in charge of the procurement, the operation and the provision of data for the Landsat programme. The operational and distribution part were transferred to the National Oceanic and Atmospheric Administration (NOAA) in 1979, under Jimmy Carter administration.[107] In 1983, the decision was made that Landsat operations would be transferred from public to private operation, leading to the transfer of Landsat mission's operation to the *Landsat Commercialization Division* of the NOAA. In 1985, the US private company Earth Observation Satellite Company (EOSAT)[108] was under contract with the NOAA to procure operation and distribution of Landsat 4 and 5. Because of lack of funding, NOAA was about to drop the Landsat programme in 1989 but the programme was saved thanks to emergency funding from the US government.[109] The Land Remote Sensing Policy Act was signed in 1992, recognising the value of Landsat by the US congress as one of the US national capability. This act has led, among others, to the transfer of the Landsat programme management from the private to the public under a joint-management of the Department of Defense (DoD) and NASA, leading to the assignation of the Department of the Interior to be in charge of the National Satellite Land Remote Sensing Data Archives. The US Geological Survey (USGS), a division of the Department of Interior, was mandated to play this role, with the Earth Resources Observation Science (EROS) centre becoming in charge of the storage of all Landsat data archives. In 1998, the contract owned by Space Imaging Corporation (formerly EOSAT) on the operation and distribution of Landsat satellites was transferred to USGS; Space Imaging Corporation would be operating Landsat 5 until 2001. After this private episode, US government has recovered the full management of the Landsat mission. Nowadays, the Landsat programme is still fully operated by USGS, NASA being in charge of procurement and launch of the Landsat satellites.

The Landsat 8 mission

The Landsat Data Continuity Mission (named Landsat 8 after on-orbit initialization and verification) was launched from Vandenberg Air Force Base in California on February 11, 2013, atop an Atlas V rocket. As with previous partnerships, this collaboration between the U.S. Geological Survey (USGS) and NASA continues the mission to acquire high-quality data that meet both USGS and NASA scientific and operational requirements for observing land use and land cover change. NASA managed the satellite during the on-orbit initialization and verification period after launch. Once the post launch assessment review and the mission transition reviews were completed, the USGS became responsible for the operations of the mission, including: health and safety of the spacecraft; orbital maintenance; and collecting, archiving, processing, and distributing data products.[110] The data received from Landsat 8 are processed using parameters consistent with all standard Landsat data products and are

107 Source: USGS website, consulted February, 06 2016.
Link: http://egsc.usgs.gov/isb//pubs/factsheets/fs02303.html
108 EOSAT was a division of Lockheed Martin that was bought by Space Imaging Corporation in 1996. Space Imaging Corporation was then bought by GeoEye in 2006 for finally being bought by Digital Globe in 2013.
109 Source: Greenberg, J.S. and Hertzfeld, H. (1992). Space Economics. American Institute of Aeronautics & Ast (AIAA). P. 372.
110 US Geological Survey(USGS), 2013. Fact Sheet 2013-3060. August 2013.
Link: http://pubs.usgs.gov/fs/2013/3060/pdf/fs2013-3060.pdf

available for download at no charge and with no user restrictions from EarthExplorer, GloVis, or the LandsatLook Viewer.[111]

The Landsat programme possesses a network of ground stations in US territory as well as international ground Stations. The main ground station is located at EROS centre in South Dakota, US, for Landsat 7 and 8, where all the Landsat data will finally end-up and being stored. The Landsat programme also have two ground stations located in Alaska (one for Landsat 7 and one for Landsat 8), as well as one station in Norway (Landsat 7 and 8) and one in Australia (Landsat 7). The stations are used to downlink data to feed the needs of the user communities that will be stored in the USGS data archives located in the EROS centre. These stations are also able to uplink commands to the satellite to choose specific geographic areas or specific spectral resolution.[112]

Landsat mission capacity

The Landsat mission is currently operating and distributing Landsat 7 and 8 data, offering optical data in different spectral resolution: in the infrared, thermal and visible spectrum. The USGS is also providing, via it web-based portal, all the archives existing since 1972 available in the EROS data centre. Raw and high level products are directly available on the USGS portal. The Landsat mission does not provide any in-situ data in their products. Landsat 8 offers multispectral bands in spatial resolution ranging between 15m and 30m, with a revisiting time of 16 days. Landsat 7 offers 7 multispectral bands in 80m and 1 band in 15m resolution (panchromatic), with a 16-day revisiting time. For the former Landsat missions, the Multispectral Scanner (MSS) of Landsat 1 to 5 offers archives of 80m spatial resolution and the Thematic Mapper (MP) of Landsat 4 & 5 offer archives of 30m spatial resolution.

Lessons learned from the public/private boundaries of the Landsat programme

The public/private boundary is one of the main concerns for most publicly-owned programmes in order to be able to find equilibrium between public and private roles. The economic theory behind public/private boundary was already discussed in the literature review part of this study. With more than 40 years of existence, the Landsat programme has a very long experience dealing with public/private boundary.

Landsat privatization experience

Historically designed as a fully public programme, the operation and distribution of Landsat were decided to be transferred to the private in the 80s once all the upstream and midstream infrastructures were developed by public investments. The operation and distribution were given to the private to push for market development around EO data, under a 10-year contract with the NOAA. The private episode of Landsat was not successful since the public/scientific market was not big enough to create a sustainable commercial demand, with public and scientific entities having low willingness-to-pay. The programme was about to be bankrupted when the US government provided them with emergency fund. The **Land Remote Sensing Act was signed in 1992** guaranteeing funding and continuity of operation for the Landsat missions. Since 1992, the Landsat programme is also considered as one of the US national capability, justifying public intervention to fund and operate the system. **The failure of Landsat privatization has not ironed out private interests for Landsat data**.

Role and responsibilities of the USGS

USGS role has evolved over the last years because users' needs have changed, responding to both public and private users. Traditionally requiring raw and corrected data, **more and more users are requiring high level products**. As a public entity, USGS has decided to provide such products in a standardized way to facilitate the dissemination of data and products for public and private organisations. The different types of products offered by **USGS** are **high level products produced on a routine basis that are not provided on a routine basis by any US commercial EO downstream actor** (at least in burned area, dynamic surface water extent, surface

111 Link towards:
Earth Explorer: http://earthexplorer.usgs.gov
GloVis: http://glovis.usgs.gov
LandsatLook Viewer: http://landsatlook.usgs.gov
112 Source: USGS website, consulted 14-04-2016
Link: http://landsat.usgs.gov/about_U_S_ground_stations.php

temperature and surface reflectance). In fact, a number of USGS users are commercial firms, including US commercial EO downstream companies. In this context, the public intervention of US government does not harm the local EO downstream commercial market. The provision of such products rather allows a better competition, guaranteeing an equal access to information for organisations of all sizes and with different backgrounds, both public and private. It leads to the creation of public knowledge on the use of EO data, pushing forward the dissemination of standardized products based on Landsat imagery.

Public investment as a spark to develop an innovative ecosystem

The Landsat experience highlights an interesting example on how a large public investment over a long period of time, more than 40 years, has led to the creation of a national capability. Indeed, the Landsat programme is ranking 2nd, just after GPS, in terms of strategic importance for the US and is **considered as a national capability**. Having this status enables the Landsat programme to be operated without need of justification from the public investment made in the programme. Over these four decades, **a large ecosystem of users has been developed around a large pool of governmental and scientific users, developing Business-to-Business (B2B) relationships to foster the development of a market**. The essential step to create the whole ecosystem was the development of a local/internal scientific market for Landsat data in the US. To achieve this major step, a gestation period was required to create a knowledge culture around the usage of EO data and enable the dissemination of Landsat EO data within communities. An important scientific ecosystem is required before the possibility of the development of a commercial market in such situation. In fact, the scientific communities contribute to the creation of a strong public knowledge locally that enable, in mid-long term, the growth of the ecosystem and leading to innovations. The following figure summarises the different steps a programme such as Landsat had to face to develop an innovative ecosystem around itself.

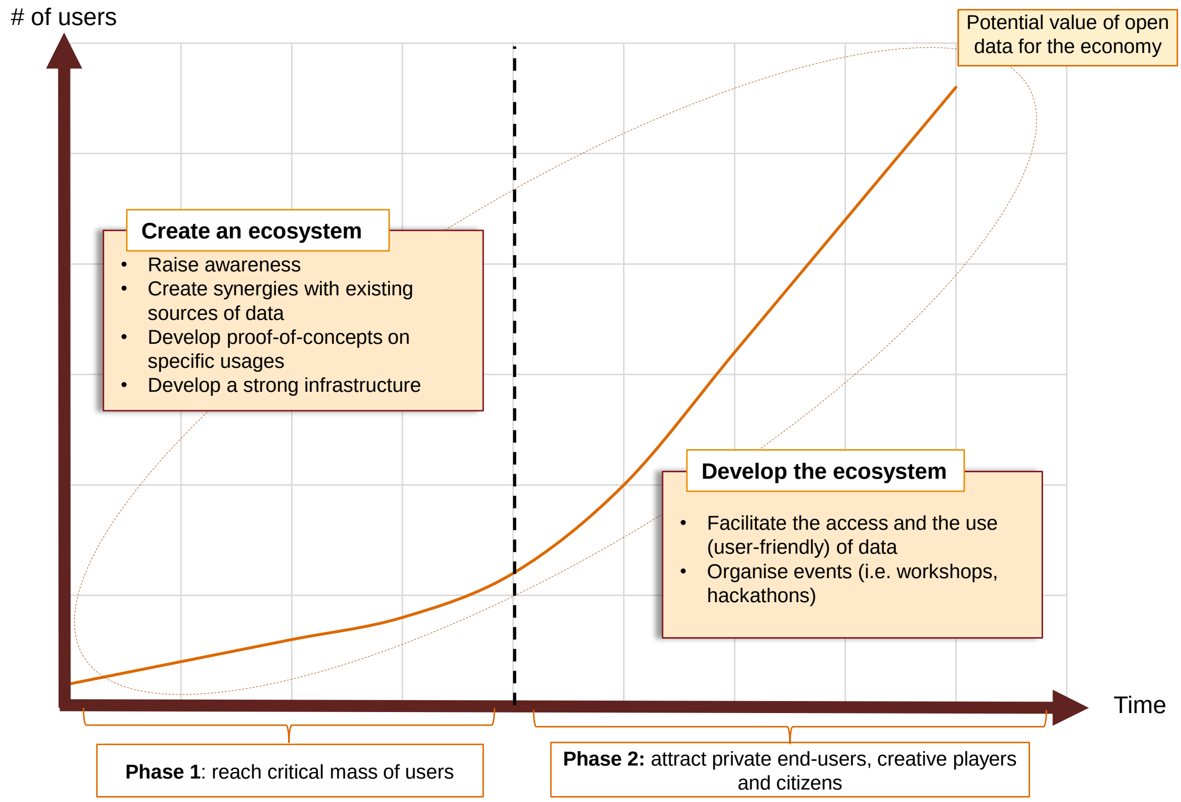

Figure 42 - Summary of the creation of an ecosystem (Sources: PwC-Strategy& analysis, based on interviews with USGS)

An innovative ecosystem can be created once a large public knowledge is available locally, enabling the reduction of barriers to entry for non-technical actors. The first phase aims at developing this public knowledge and at disseminating the use of Landsat data in different communities. This first phase also enables to raise awareness on the availability of open data. The availability of a large critical mass of scientific users gives the spark to the development of the second phase. Once a critical mass of users is reached, private companies and other non-technical actors have incentives to enter on the market to create value thanks to the public knowledge available. The second phase aims at developing the ecosystem facilitating the access and the use of data to wider communities. This phase, once public knowledge on EO is available, enables the dissemination of data through facilitation of access to data thanks to user-friendly APIs, data-ready-to-analysis or basic products. The development of dedicated workshops and specific events such as hackathons lead to the creation of important value for the society, both in terms of societal and economic impact.

The socio-economic value of the Landsat imagery

This section focuses on the socio-economic value of the Landsat imagery. All the content provided in this section is derived from an intense interaction with the socio-economic team of the USGS and all USGS publications related to socio-economic assessment of the value derived from Landsat imagery. Table 12 summarises the willingness-to-pay of US and international users per Landsat scene.

	US users (per scene)				International users (per scene)			
	Established User	90% Confidence Interval and Lower Bound	New & Return	90% Confidence Interval and Lower Bound	Established User	90% Confidence Interval and Lower Bound	New & Return	90% Confidence Interval and Lower Bound
Median	USD 182,00	USD 157-207	USD 49,00	USD 42-55	USD 171,00	USD 146-205	USD 59,00	USD 56-64
Mean (average)	USD 912,00	USD 829,00	USD 367,00	USD 341,00	USD 930,00	USD 842,00	USD 463,00	USD 425,00

Table 12 - Willingness-to-pay per type of users of Landsat imagery (Source: USGS, 2013)[113]

The average value varies a lot from establishes users – long term users – and new or returning users, ranging from USD 912 per Landsat scene for the established US users to USD 367.00 for the new and returning international users. Moreover, the willingness-to-pay seems quite high. In fact, average value interpretation is very sensible to extreme values, so if some users express very high or low willingness-to-pay, the final value can be easily biased. Median is way lower compared to average value for Landsat imagery for both types of users, meaning the sample should include many high extreme values. In this context, a focus should be made on the median ranging for US users from USD 182 (established users) to USD 49 (new & returning users) and for international users from USD 171 to USD 59.00.

Many case studies were produced by the "Social and Economic Analysis Branch" of the USGS. The following sub-sections present some of them, with a particular attention to the case studies related to the sectoral uses analysed for the Copernicus programme in this study when applicable. Note that Landsat and Copernicus using different type of sensors, the type of applications differs from one programme to another, with a particular focus on agriculture and water management in the case of Landsat.

Most of the case studies do not include any economic figures due to the difficulty to assess the economic value of a free and open EO data such as Landsat imagery.

Agriculture: Vineyards monitoring, improving irrigation technology and grape & wine quality using Landsat imagery in the US wine company E. & J. Gallo.

Landsat imagery is increasingly used in the private sector. E. & J. Gallo (Gallo), located in California, is the largest winery in the world and the first known company in the U.S. beverage industry to use Landsat data in viticulture practices. A pioneer of efficient water-management practices through Landsat, Gallo uses the imagery on approximately 20,000 acres of Gallo-owned vineyards from Southern California to Mendocino County. Evapotranspiration from vineyards is the primary interest, though other crops are also gaining attention, particularly when looking at land acquisition and water availability in various regions. Gallo's goals with using Landsat imagery include:

- Estimating the potential water use for vineyards by region and varietal,
- Estimating actual water use for irrigation and water stress index,
- Scanning every vineyard owned or purchased (approximately 150,000 acres) to develop area specific water budgets,

113 USGS, 2013. Users, Uses and Value of Landsat Satellite Imagery, Results from the 2012 Survey of Users.

- Supporting land acquisition based on water availability and quality.

Currently, Gallo downloads every available Landsat image during the grape growing season. Irrigation generally starts in March in the warmer areas and continues through the month of October. An adjusted form of METRIC (Mapping EvapoTranspiration at high Resolution with Internalized Calibration) is then used to map evapotranspiration of the vineyards. The METRIC model was originally designed to compute and map evapotranspiration based on Landsat images. Gallo developed an internal calibration of METRIC which is currently used by the company in vineyards. Operation of the METRIC model depends on Landsat's thermal data availability. Some of the benefits that Gallo observed in the last three years of using Landsat imagery include:

- Decrease in the amount of water applied by 20–30 percent, subject to region,
- Improved water management with the ability to run a seasonal water balance,
- Development of more efficient seasonal irrigation schedules,
- Improvement in grape quality which leads to improved wine quality,
- Upward movement in the wine program, due to higher grape quality, leading to an increase in bottle price and an increase in revenue,
- Reduced trimming of excess leaf canopies from over-irrigation,
- Decrease in the cost of irrigation from reduction of water and energy used,
- Using current year's data of water allocation to determine and plan next year's allocation.

Not only is Gallo able to supply consumers with better quality products through the use of Landsat imagery, but they are also able to decrease their business' impact on the environment through a decrease in the amount of water applied during the irrigation season. The benefits from a reduction in application range from retention of in-stream flows to water-quality improvements due to decreased runoff.

Although other satellite imagery is available, the resolution is not as high as that of Landsat, and thus the data is not as useful for Gallo in this type of field application. However, Landsat itself also brings a variety of challenges. Cloud cover, for example, presents issues when obtaining data. Landsat 5 contributed significantly to the frequency of data availability as it shortened the lag between available images. One operational Landsat satellite is capable of providing an image every 16 days, and if an image contains cloud cover, it is not usable and is a loss of data. Timely and continued thermal data is particularly valuable in agriculture, as consumptive water use changes seasonally, even monthly. An increase in the frequency of imagery promotes efficiency of irrigation schedules. An increase in the number of operational Landsat satellites increases the benefits derived and improves assurance of data availability.

Gallo continues to use Landsat imagery with goals to expand its application through the Pacific Northwest and its international properties. Although significant benefits to Gallo and the environment (and, in turn, to society) are observed with the company's use of Landsat imagery, Gallo could not afford to purchase satellite imagery alternatives to Landsat, nor afford a privately operated satellite. Understanding the current and potential benefits of the imagery use, Gallo expresses great interest in supporting the Landsat mission.[114]

Authors: Larisa Serbina and Holly Miller

Agriculture, vineyards and apple & olive orchards monitoring in Chile using Landsat imagery

Landsat has been instrumental in helping Chile estimate water demand. The country often faces drought conditions, and although some level of water supply is guaranteed from dams and reservoirs, seasonal supply is uncertain. Agricultural production is a large enterprise in Chile, and water shortages create uncertainty in agricultural production as well as economic growth and sustainability. Landsat imagery allows the country to estimate seasonal demand and match it against seasonal supply to achieve optimal irrigation practices for maximum production. Landsat data and the METRIC model are being used in Chile for the estimation of consumptive water use. Using this information, water budgets are created and a more accurate estimate of water demand is calculated. In conjunction with METRIC, Landsat data are being used to estimate evapotranspiration and the crop coefficient for olive and apple tree orchards as well as vineyards. The output is used to develop water-management strategies on farms and at the regional level.

Landsat data became available at no cost in 2008. This has had a significant effect on the extent of its applications, although its use in Chile by Dr. Samuel Ortega of the Universidad de Talca started a few years earlier, using only a few purchased scenes to launch the current research. Since 2005, over 500,000 acres of olive and apple orchards

[114] *Source: Martin Mendez, E. & J. Gallo, oral communication and written communication with USGS, 2013.*

as well as vineyards have been surveyed using Landsat and METRIC to estimate regional and local consumptive use for water budgets. Landsat imagery allows adjusting the application of water on each vineyard based on water requirements for a specific production outcome. A Landsat-based recommendation of delaying the start of irrigation from September to November has saved up to two months of irrigation water in some regions for producers enacting the practice. While using Landsat imagery to help identify the most accurate crop water requirement on private agricultural lands at the farm level, the following benefits have been observed:

- A $80/acre cost savings in energy used for irrigation on over 3,700 acres of olive orchards per year,
- A 30 percent to 60 percent reduction in the amount of water applied on grapevines on 6,000 acres, and
- An increase in grape quality between 30–35 percent.

Water budgets allow for the control of water application and adjustment of the crop water coefficient. This enables strategic planning for water application and yields higher quality grapes. Although higher quality grapes correlate with lower production amounts, the profits are offset by higher wine quality and a higher price per bottle. An increase from $1.00 to $20.00 per bottle from water-application adjustment has been observed in some of the plots where Landsat imagery is used to adjust irrigation practices. Additionally, a decrease in irrigation energy cost, as a result of a smaller amount of water applied, contributes to the overall increase in profit.

As evident by the examples provided, Chile has been able to use Landsat imagery to improve agricultural production and use a scarce resource more efficiently. Government officials in Chile seek consumptive-use information from Landsat and METRIC to help drive informative policy decisions regarding water supply, storage, and allocation. The long term goal from using this technology would be to establish a water market. Although some challenges exist with current Landsat output, due to issues such as cloud cover and 16-day repeat coverage which limit the amount and quality of usable data, Landsat remains the main source of moderate resolution imagery with thermal data used for work in water resources ongoing in Chile.[115]

Authors: Larisa Serbina and Holly Miller

Agriculture: USDS Estimation of Crop Production

Remote sensing, including Landsat satellite imagery, plays an important role in developing crop production estimates. In particular, the use of satellite imagery plays an important role in enhancing the accuracy and reliability of global crop production estimates.[116] Domestically, satellite imagery provides supplemental data to annual ground-based agricultural surveys. In addition to supplementing annual estimates, the ability of satellite imagery to provide near real-time production estimates of major crops is increasing, with significant strides occurring within the last decade. The task of estimating crop production is the responsibility of the National Agricultural Statistics Service (NASS) for domestic (U.S.) production and the Foreign Agricultural Service (FAS) for all global production (excluding the U.S.).

Developing crop production estimates requires accurate assessment of two primary inputs: crop acreage and yield. Crop acreage is a measure of the land area in production while yield is an estimation of the productivity of that area. Currently, both the NASS and FAS rely on Landsat and DMC satellite imagery as primary sources for developing crop acreage estimates. Using a combination of red, near-infrared and shortwave infrared (only on Landsat) bands, acreage is derived using classification algorithms that can differentiate between specific crops. With two Landsat satellites currently in operation (7 and 8), a new moderate resolution (30-meter) scene can be acquired as often as every eight days. This interval represents ideal conditions as, realistically, most locations have an effective acquisition rate of a few cloud-free scenes per growing season.

Yield estimates, when based on satellite imagery, rely primarily on vegetation indices, such as the Normalized Differential Vegetation Index (NDVI) to monitor crop phenology.[117] Broadly speaking, crop phenology can be divided into emergence, vegetative growth, flowering, fruit/seed development, and maturity. Crop coefficients, which are unique for each crop and based on the relationship between historic crop phenology and yield data, are then applied to estimate potential yield for the current crop.

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[115] *Source: Samuel Ortega, Universidad de Talca, oral communications and written communications with USGS, 2013.*

[116] *Source: Vogel, F.A. and Bange, G.A., 1999. Understanding USDA Crop Forecasts. Miscellaneous Publication. No. 1554. Washington, DC, USA.*

[117] *Source: Prasad, A. Chai, L., Singh, R., and Kafatos, M., 2006, Crop yield estimation model for Iowa using remote sensing and surface parameters. International Journal of Applied Earth Observation and Geoinformation. V. 8, No. 1, p. 26-33.*

NDVI for both NASS and FAS is primarily derived from imagery collected by the MODIS sensors on-board the Aqua and Terra satellites. At 250 meters, MODIS has significantly lower spatial resolution than Landsat. However, the higher revisit frequency of 1 to 3 days provided by the Aqua and Terra satellites is preferable to a higher resolution from Landsat, as crop phenology is dynamic throughout the growing season. MODIS imagery can also be used to derive crop acreage estimates: however, finer spatial resolution (such as Landsat 30-meter) significantly improves both the appearance and accuracy of crop classification.[118] Currently, Landsat acreage estimates are used as an input mask to help increase the accuracy of MODIS NDVI. While this is generally a viable workaround, yield estimates cannot be made to the field level, which would require Landsat resolution imagery collected at a high enough frequency to provide global NDVI monitoring.

Benefits and Challenges of Using Landsat Imagery

For both the USDA, the benefit of using Landsat for crop monitoring is that the imagery provides an objective and unbiased assessment of farm-level crop production. The known stability of spectral and spatial resolution across Landsat satellites as well as the high level of image-data orthorectification and radiometric correction have helped establish Landsat as a gold standard among earth observation satellites. The thirty-meter image-pixel resolution of the multi-spectral data collected by Landsat since 1982 has become a standard for land cover classification, enabling a high level of classification accuracy while balancing the processing realities of classifying imagery at a global scale[118]. In practical terms, the availability of consistently collected (across multiple satellites/years), accurately corrected, and as of 2008, freely available, Landsat data is an important benefit for agencies such as the FAS, which remain primarily operational in nature with limited time and budget for purchasing satellite imagery from commercial sources[119]

The recent launch of Landsat 8 in 2013 has helped ensure the continuity of the Landsat mission. However, between 2003 and 2013, the primary challenge facing agencies like the USDA was uncertainty in the long-term outlook of the Landsat program and the pending data gap due to an aging Landsat 5 and SLC-off issue with Landsat 7[118]. Although Landsat 8 became fully operational in 2013, a number of challenges related to agricultural monitoring remain. The primary challenge is low global repeat frequency, which continues to provide a data gap for global agricultural monitoring. Occlusion of the land surface by clouds, such as over Brazil's soybean region bordering the Amazon forest or for the Ethiopian Highlands, remains the main challenge, where generally only one cloud-free image is acquired per year. Ethiopia remains one of the largest U.S. food aid recipients and therefore of high interest for crop production monitoring, while Brazil has become one of the largest soybean producers in the world. While the concurrence of agricultural production with high rainfall means occlusion by clouds, prioritization of agricultural monitoring needs within the Landsat 8 Long Term Acquisition Plan could potentially increase the number of usable Landsat images obtained within major agricultural regions worldwide.[119]

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Forestry: SilviaTerra, Landsat imagery used by a forestry start-up

SilviaTerra is a four-year-old start-up company with five full-time employees that is contributing to the change in the way forests are managed in the United States. The company provides next-generation, highly accurate forest inventory data to fifteen users of various sizes. The customer base includes national and international timber companies. SilviaTerra is profitable and continues to grow.

The launch and success of this company are in no small part due to the free availability of Landsat imagery. Other technologies are utilized in the development of the final product, although this work could not be accomplished without Landsat's free availability of red, green, blue and infrared bands. Potentially, SPOT imagery could be used as an alternative. However, the cost of using SPOT for a nation-wide inventory would be prohibitively high for the company. "With a full-retail price of $3,666 per scene and the need for an estimated 6,000 scenes to cover the U.S., the total cost without annual updates could amount to $22 million," says Max Nova, founder and Lead Engineer at SilviaTerra[120]. Even with potential bulk discounts, the cost of alternative imagery would create roadblocks for this start-up. Additionally, SPOT has higher spectral resolution, which Nova notes would impose more processing and analysis time. Thus, Landsat imagery, due to its spectral resolution and free and open data policy, remains the most preferred option for this start-up.

[118] Source: Johnson, D., and Mueller, R., 2010, The 2009 Cropland Data Layer. Photogrammetric Engineering & Remote Sensing. V. 76, No. 11, p. 1201.
[119] Source: Curt Reynolds, USDA FAS, written communications and oral communications with USGS, 2014.
[120] Source: Nova, Max, SilviaTerra, oral and written communication with USGS, 2014

Landsat has enabled SilviaTerra to set and achieve big goals within the forest industry. The company plans to generate a complete forest inventory for the entire U.S. The company strives to have the inventory available for a variety of users and update it yearly. Nova points out that SilviaTerra helps forest managers make better decisions through the availability of better data. For any forest larger than 10 acres, SilviaTerra can determine the diameters and species of trees in that area with 95% accuracy for trees per acre and basal area using Landsat, National Agriculture Imagery Program (NAIP), and Digital Elevation Models (DEMs)[120]. This assessment capability not only allows forest companies to determine optimal cutting, planting, and fertilizing schedules to optimize profits, but also enables them to comply with complex environmental regulations.

Nova also mentions that SilviaTerra is aiming to expand its customer base expanding beyond the larger timber companies to private land owners. Most forests in the U.S. are owned by small private landowners and only a small fraction (10-20%) has a documented forest management plan. These plans must be based on forest inventory, which is often cost-prohibitive for small landowners to obtain. SilviaTerra is working with local forestry consultants across the U.S. to provide individual landowners with the data they need to manage and improve their land, something that would not be economically viable for SilviaTerra to provide without free and open access to Landsat imagery. The company envisions a future where every acre of forest in the United States has a well-informed management plan.

Authors: Larisa Serbina and Holly Miller

Disaster Monitoring: Flood Extent and Disaster Monitoring in Australia using Landsat imagery

In Australia, between 1852 and 2011, at least 951 people were killed by floods, another 1,326 were injured, and the cost of damage reached nearly $5 billion dollars. More recently, the southeast Queensland floods during the 2010–11 season left much devastation, destroying 75 percent of the banana crop and, as a result, inflating banana prices.[121] Floods have devastated communities and negatively impacted the regional and national economies in Australia. Landsat imagery, in conjunction with MODIS and several other commercially acquired satellites, has been used to map flood extent to provide situational-awareness information to emergency services in order to save lives and mitigate economic impact.

During June 2007, the Gippsland region in south-eastern Victoria experienced heavy rainfall and widespread flooding. Geoscience Australia used Landsat 5 satellite images of the area around Bairnsdale and Sale, acquired two weeks before the heavy rains and then around the flood peak, to determine the extent of flooding[122]. Visual comparison of a Landsat image acquired on June 13, before the flood, with an image taken on June 29, showed the inundated areas clearly (fig. 1A and B). In the first image, the Mitchell River is a thin, meandering black line flowing into Lake King, while the second image shows the inundation of areas around Bairnsdale, as well as the Mitchell River breaching its banks[122]. Geoscience Australia provided the map of surface water extent derived from satellite images to the State Emergency Services in Victoria for their assessment and use. Feedback indicated that the satellite-derived information complemented local information available to emergency managers during the disaster. Information on flood extents is invaluable for emergency authorities involved in flood recovery and damage assessment. Prompt delivery of such information to emergency managers helps them prioritize their response activities. This enables flood managers to save more lives while spending less money and time on identifying flood extent[122].

During the 2010–11 flooding of Queensland and New South Wales, Geoscience Australia provided over 100 Landsat images to and derived flood extent products for the Queensland Department of Community Safety and related emergency services. Landsat data was used to help plan access to flooded regions, sites for food and medical supply stations, and to help assess the progress of floods as they moved across inland floodplains. The resulting data were used to determine the extents of several flood plains and the locations of water diversion structures.[123]

Authors: Larisa Serbina and Holly Miller

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[121] *Source: Carbone, Delana, and Hanson, Jenna, 2013, The worst floods in Australian history: Australian Geographic. Accessed on May 16, 2013*
Link: http://www.australiangeographic.com.au/journal/the-worst-floods-in-australian-history.htm.
[122] *Source: Thankappen, Medhavy, 2007, Gippsland flooding revealed: AusGeo News, No. 87. Accessed on May 16, 2013*
Link: http://www.ga.gov.au/ausgeonews/ausgeonews200709/gippsland.jsp
[123] *Source: Norman Mueller, Geoscience Australia, written communication with USGS, 2013*

Recommendations

Strategic pillar	Sectoral recommendations for policy action	Priority level
Pillar I: Ensure access to data	***#LAN-1 - Develop a dedicated connection for large-volume users*** The development of a dedicated connection for large volume users (both public and private) different from general throttling has largely contributed to the dissemination of Landsat data. The Copernicus programme should develop a similar access on a one-by-one basis to foster the use of Copernicus data since this type of users will download all the data anyway. In such context, the Copernicus programme should better use a collaborative approach than a conflictual one following the rules of Game Theory.	1
Pillar I: Ensure access to data	***#LAN-2 - Simplification and mutualisation of the Copernicus data access to avoid duplication at national and international level*** The Landsat programme is offering an easy and simple access to data and Landsat products worldwide for both US and international users. The Landsat access is an interesting example of architecture that enables to avoid duplication of efforts and wasted cost. The Copernicus programme should work on a simplification and mutualisation of it data access architecture. Moreover, more links with organizations such as the USGS should also be pushed forward to work on a collaborative approach, complementing and promoting what these organizations are offering to avoid duplications and wasted costs at international level.	1
Pillar II: Support innovation	***#LAN-3 - Copernicus core services should focus on the creation of public knowledge related to Copernicus products and data*** The aim of a programme such as Copernicus is to give the spark to foster the use of EO data in scientific, public and private operations of the European society. The public should be developing a fertile ground for innovation, investing to create a large public knowledge on how to process, use and analyse Copernicus data in a very specific context. Collaborations with universities and public & private administrations should enable the creation of these knowledges, contributing in the end to European economic growth.	1
Pillar III: Increase awareness	***#LAN-4 - Increase collaboration with open source and crowdsourcing communities*** Such as the USGS with Github, the Copernicus programme should push forward collaborations between Copernicus core services and crowdsourcing & open source communities. Using open innovation strategies will help raise awareness about the availability of Copernicus data for free and attract outsider from other communities, especially the coder, software and IT communities.	2
Public/Private Boundary	***#LAN-5 - Find the right equilibrium between public and private role*** Providing basic standardized information products on a routine basis plus data ready for analysis (e.g. data cubes of specific areas of interests derived from user requirements) should contribute to the dissemination of Copernicus data, especially for less technical actors. In fact, these types of product contribute to foster both the institutional and private market.	2

Part (d) – Analysis of Copernicus opportunities on sectoral value chains

Overview of all areas using Copernicus data

The Copernicus programme brings value-added to numerous sectors. The data provided by the Copernicus programme enable miscellaneous applications, which ease the daily lives of end users and help those making decisions.

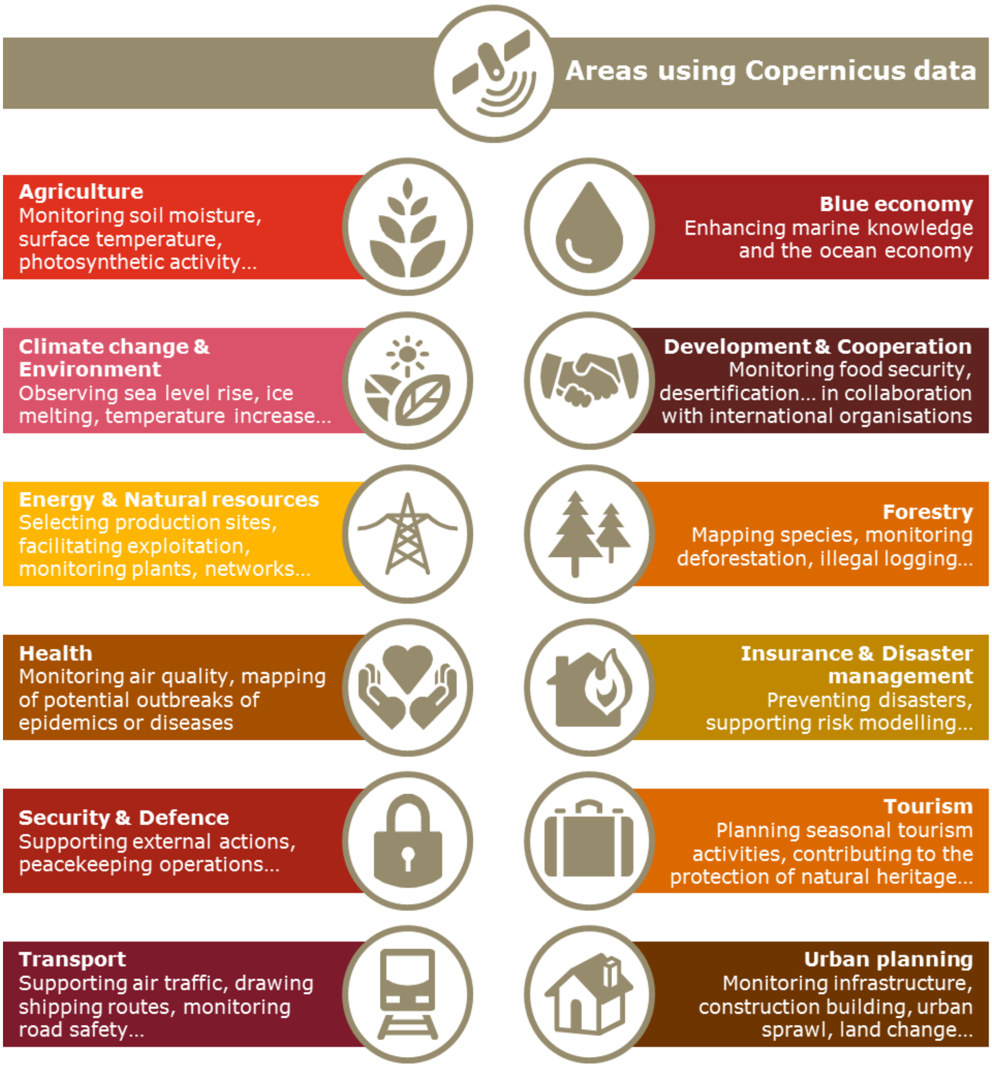

Figure 43 - Areas using Copernicus data (sources: PwC-STRATEGY& analysis[124] & European Commission[125])

[124] *European Commission, 2015.* Space tech and services - Applications related to Earth Observation - Case study 63

[125] *European Commission, 2015.* Copernicus Brochure

This part of the report focuses on 8 promising sectors where Copernicus is used: Agriculture, Forestry, Ocean monitoring, Insurance related to natural hazards, Renewables energies, Oil & Gas and Mining, Urban monitoring, and Air quality management.

Sectoral Value Chain

Agriculture

Key specificities
➢ **Historically, agriculture was one of the first domains to make use of space-enabled Earth Observation data and services.** ➢ **The majority (approximately 90%) of EO applications in the agricultural sector focus on precision farming techniques.** ➢ **Intermediate users are very heterogeneous: start-ups and SMEs, larger players, pure scientific players such as research organisations and universities.** ➢ **The typology of end users includes both public actors (such as governmental authorities which are in need of obtaining precise information in the framework of specific policies and regulations, or to monitor specific issues such as food security or droughts), and private actors (agricultural corporations, food companies, etc.).** ➢ **In 2015 the revenues from the European precision farming European market directly enabled by Copernicus represent 2.49% (minimal estimation) of the total revenues and should reach 17% by 2020.** ➢ **Farmers, who account for most of the potential end users of agricultural products based on EO data, cannot generally afford to pay for such services. Thus, in many cases the direct clients of intermediate users are agricultural cooperatives which then distribute the products to the farmers they represent.** ➢ **Sentinel-1 and 2 data is used by many public and private service providers in order to develop their products and applications.**

Scope/boundary

EO enabled agricultural-related applications add value to a number of sub-sectors: crop-related activities (such as crop health monitoring, crop inventories, crop types monitoring), water management (related to soil moisture, to the irrigation of crops, drought monitoring), as well as land use optimisation and management (assessing changes in land use and quality, etc.). The analysis of the socio-economic impacts of the Copernicus programme along the agricultural value chain will take into account all the above sub-sectors with a specific focus on precision farming techniques as well as the precise contribution of Copernicus data to better monitor food security issues (including the prevention and monitoring of droughts, crop monitoring at different scales, etc.).

Taxonomy and definitions

Main definitions related to the agricultural value chain	
Agricultural system	An assemblage of components which are united by some form of interaction and interdependence and which operate within a prescribed boundary to achieve a specified agricultural objective on behalf of the beneficiaries of the system.[126]
Food security	Food security can be defined as including both physical and economic access to food that meets people's dietary needs as well as their food preferences. It is based on three pillars: food availability, food access and food use.[127]
Land	A delineable area of the Earth's terrestrial surface, encompassing all attributes of the

[126] *FAO, 1997.Farm Management for Asia: a Systems Approach. Link: http://www.fao.org/docrep/w7365e/w7365e04.htm*
[127] *World Health Organization. 2016. Food Security. [ONLINE] Available at: http://www.who.int/trade/glossary/story028/en/. [Accessed 3 June 2016].*

	biosphere immediately above or below this surface including those of the near-surface climate the soil and terrain forms, the surface hydrology (including shallow lakes, rivers, marshes, and swamps), the near-surface sedimentary layers and associated groundwater reserve, the plant and animal populations, the human settlement pattern and physical results of past and present human activity (terracing, water storage or drainage structures, roads, buildings, etc.)[128].
Land applications	According to the EARSC taxonomy, land applications cover all types of applications which are focused on natural land areas even if they involve human intervention.
Land use	The arrangements, activities and inputs people undertake in a certain land-cover type to produce, change or maintain it.[129]
Precision farming	Managing crop production inputs (seed, fertilizer, lime, pesticides, etc.) on a site-specific basis to increase profits, reduce waste and maintain environmental quality.[130]
Sustainable agriculture	The efficient production of safe, high quality agricultural products, in a way that protects and improves the natural environment, the social and economic conditions of farmers, their employees and local communities, and safeguards the health and welfare of all farmed species[131].

Value chain description

Overview of industry/domain

Land exploitation in agriculture provides a critical food supply that feeds the Earth's human population of 7 billion, fibre for a variety of purposes and a critical resource for sustainable development in many regions. Agriculture is frequently central to the livelihoods of many individuals, and is a key economic sector in developing countries.

The agricultural supply chain involves numerous actors and goes from production, to food processing and finally distribution and retail. The ultimate objective is to produce food for the consumers.

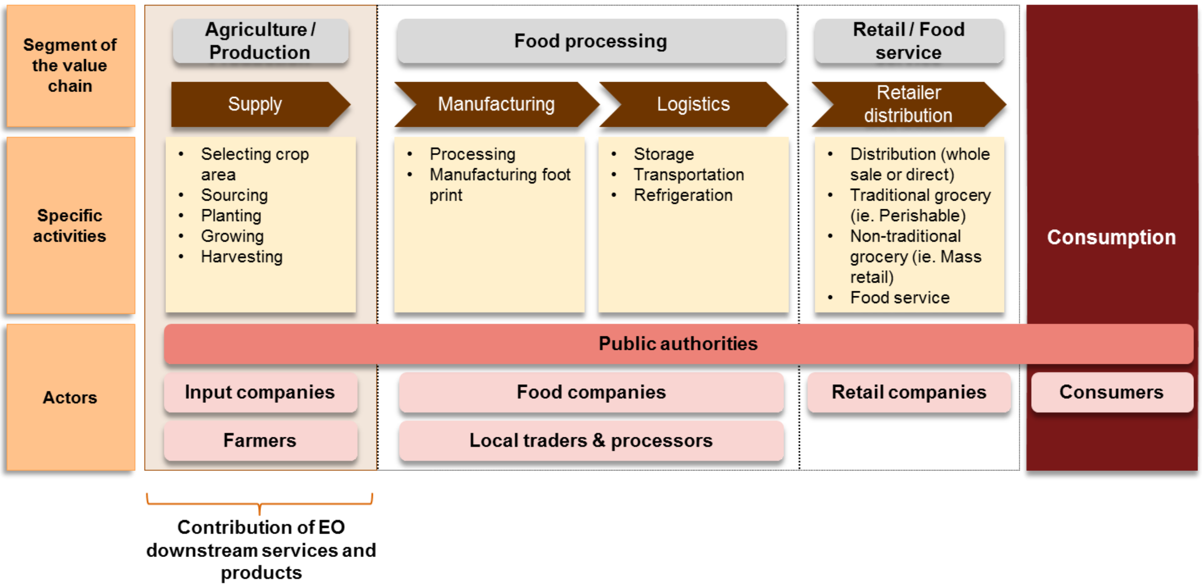

Figure 44 - Generic supply chain of the Agricultural sector (Source: PwC-Strategy& analysis)

The main types of actors involved in the agricultural supply chain are the following:

- **Farmers**: the main actors in the agricultural sector
- **Input companies**: which provide and sell agricultural inputs such as pesticides, fertilizers, seeds, etc.
- **Public authorities**: in charge of the establishment and monitoring of agricultural policies
- **Food companies**: principally involved in the logistics and distribution segment of the supply

[128] *UN, 1994. Convention to Combat Desertification.[Link : http://www.fao.org/docrep/v8047e/v8047e04.htm]*
[129] *FAO, 1999. Land Use, what is land use. Link: http://www.fao.org/nr/land/use/en/*
[130] *PrecisionAG. 2015. Precision Agriculture: Terms And Definition. [ONLINE] Available at: http://www.precisionag.com/business/precision-agriculture-terms-and-definitions/. [Accessed 3 June 2016].*
[131] *Sustainable Agriculture Initiative Platform. 2010. Definition . [ONLINE] Available at: http://www.saiplatform.org/sustainable-agriculture/definition. [Accessed 3 June 2016].*

- **Local traders and processors**: who make the link between the farmers and the retail companies or food cooperatives
- **Retail companies**: who buy goods from the food companies, manufacturers and local traders and sell them to consumers
- **Consumers**: which encompass the urban and rural consumers

The agricultural sector, because of the vital role played in the global economy, is rapidly evolving due to the emergence and development of numerous techniques and the changing environment. According to the Food and Agricultural Organisation (FAO), changing land-use practices, technological advancement and varietal improvement have enabled **world grain harvests to double from 1.2 to 2.5 billion tonnes per year between 1970 and 2010**[132]. This progress is particularly pressing in the context of rising food security issues. Global population is expected to reach 8.3 billion by 2030[133] and place even greater pressure on natural resources. According to the FAO, **agriculture production needs to increase by 60% globally to address food security issues**. In order to be able to respond to the growing demand in terms of agricultural resources, there is a need to **combine technical progress and political actions**. As an example, to reach the economic potential of yields, crop management practices need to be improved. EO data can contribute to improving crop management practices via for example adding value to precision farming techniques in order to enable farmers to gain efficiency and better monitor their crops.

In parallel, the need for increased agricultural productivity has been translated into action through various EU directives and policies such the Rural Development Policy 2007-2013[134], aiming at boosting the competitiveness of the agricultural sector. In this case, EO data can potentially contribute to shaping national and European policies by making available large scale and reliable data on the state of crop production.

The effect of global warming on agriculture has been subject to much debate. Although the impact on crop production currently remains uncertain, it imposes additional constraints on the world's natural resources. Moreover, agriculture is the major user of water, **accounting for 70% of the world's freshwater withdrawals**, a figure which could double by 2050[135]. Water resource management to ensure sustainability is particularly important in the African continent, where food security is a pressing issue. Satellite derived information can be used in order to better anticipate, prevent and monitor droughts, especially in regions where drought monitoring systems are non-existent. The Global Drought Information System (GDIS) for example, established by the GEO, provides a range of services aimed at the better monitoring of droughts[136].

Intensive agricultural activities may have negative impacts on the environment. As a matter of fact, some cultivated areas are characterised by unsustainable human activities that may be caused by rapid economic development and urbanisation in developing countries that put land at risk. As an example, in Europe, inappropriate land management practices account for approximately 970 million tons of soil loss/ year due to erosion[137]. Sustainable agriculture is a rising priority on the political stage - the 2030 Agenda for Sustainable Development sets as its second goal, "End hunger, achieve food security and improved nutrition and promote sustainable agriculture"[138]. The combined contributions of EO data in the above sectors might contribute to achieving the objectives of sustainable development.

Value chain characterization from an EO data usage standpoint

Current use of EO data

[132] Food and Agricultural Organisation, 2015. Global database of GHG emissions related to feed crops, Methodology. Link: http://www.fao.org/fileadmin/user_upload/benchmarking/docs/leap_methodolgy_draft.pdf
[133] UN DESA PD. World Population Prospects : The 2015 Revision, Key Findings and Advances. 2015
[134] European Commission, 2008. EU rural development policy 2007–2013. Link: http://ec.europa.eu/agriculture/publi/fact/rurdev2007/2007_en.pdf
[135] OECD, 2010. Sustainable Management of Water Resources in Agriculture. OECD. Paris, France.
[136] Group on Earth Observation, 2016. Global Drought Information System (GDIS). [ONLINE] Available at: https://www.earthobservations.org/activity.php?id=16. [Accessed 3 June 2016].
[137] Joint Research Centre, 2015. Soil area the size of Berlin lost each year due to water erosion in the EU. Link: https://ec.europa.eu/jrc/en/news/soil-area-size-berlin-lost-each-year-due-water-erosion-eu.
[138] United Nations. 2015. Transforming our world: the 2030 Agenda for Sustainable Development. [ONLINE] Available at: https://sustainabledevelopment.un.org/post2015/transformingourworld. [Accessed 3 June 2016].

(M EUROS)	Overall EO downstream market	% of the overall market for agriculture only	EO downstream revenues for agriculture
2012	786	7.50%	58.95
2015	911	7.80%	71.06

Table 13 - EO downstream revenues in Europe for the agricultural industry (Sources: EARSC; PwC-Strategy& analysis)

With a world production value of approximately EUR 3 Million and with 38 per cent of the world's land used,[139] the potential impact of applications related to EO data on the **agricultural sector** is extensive. EO contributes to the upper segment of the supply chain and particularly to the first four steps: selecting crop area, sourcing, planting and growing.

Historically, agriculture was one of the first domains to leverage space-enabled EO data and services. Today, a wide range of EO-based services are being used, based on various sources of data: ground based information, low, mid and high resolution data from public and private satellites. In 2015, agriculture was the fifth largest EO market by revenue (out of 22)[140]. As indicated in the previous table, since 2012, the market share of agricultural EO services within the overall EO market increased slightly from 7.50% to 7.80%, which represents an increase of 17% in 3 years only.

The aforementioned table gives a conservative estimate of the value of the EO downstream market based on EARSC figures. In order to obtain a higher estimate, it would be useful to take the value of the GIS market on the whole provided by Technavio[141], as stated in the below table. By deducting the portion of the value of the EMEA market related to the Middle East and by taking into account only the products related to services and data, the value of the market could be estimated at EUR 1,352 Million, significantly higher than the EO downstream market. Considering that the share of applications related to agriculture in the GIS market is similar to that for the EO market, the high estimate of the GIS revenues related to agriculture would account for EUR 105.65 Million, which corresponds to an additional 48% from the value of the EO downstream revenues for agriculture.

(M EUROS)	Overall GIS market for Europe	% of the overall market for agriculture only	GIS revenues related to agriculture
2015	1,352	7.80%	105.65

Table 14: GIS revenues in Europe for the agricultural industry (Sources: Technavio; EARSC; PwC-Strategy& analysis)

EO data contributes significantly to the identification and quantification of variations, i.e. use of water, of various agricultural inputs, across the farm in order to tailor farming practices according to specific plant needs, which is more commonly referred to as **precision farming** or **specific crop management**[142]. Based on stakeholders' views and market analysis, precision farming applications represent, by far, the majority of the products developed by service providers.

These techniques enable farmers to make a **more efficient and appropriate use of agricultural inputs** such as fertilizers, seeds, pesticides; and thus increase their productivity. Precision farming can support farmers to better monitor issues related to **the development and emergence of weeds** (in order for example to control the purity of seeds) and of illnesses linked to intensive pulverization of inputs. More specifically, EO data allows farmers to monitor large areas while producing at a high efficiency and by saving manpower. The figure below shows the different techniques used by farmers to achieve precision farming – satellite imagery being one of them, currently increasing in terms of percentage of the market.

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[139] *Food and Agriculture Organization. 2013.*

[140] *EARSC (2015). A survey into the State AND Health of the European EO Services Industry. Prepared by EARSC under assignment from ESA, September 2015.*

[141] *Technavio. Global GIS Market 2016-2020. 2015.*

[142] *INSEAD Social Innovation Centre. 2010. Farmstar goes global: Corporate Entrepreneurship Bringing Sustainable Value Innovation to Agribusiness. [ONLINE] Available at: http://centres.insead.edu/social-innovation/what-we-do/documents/Farmstar.pdf. [Accessed 10 May 2016].*

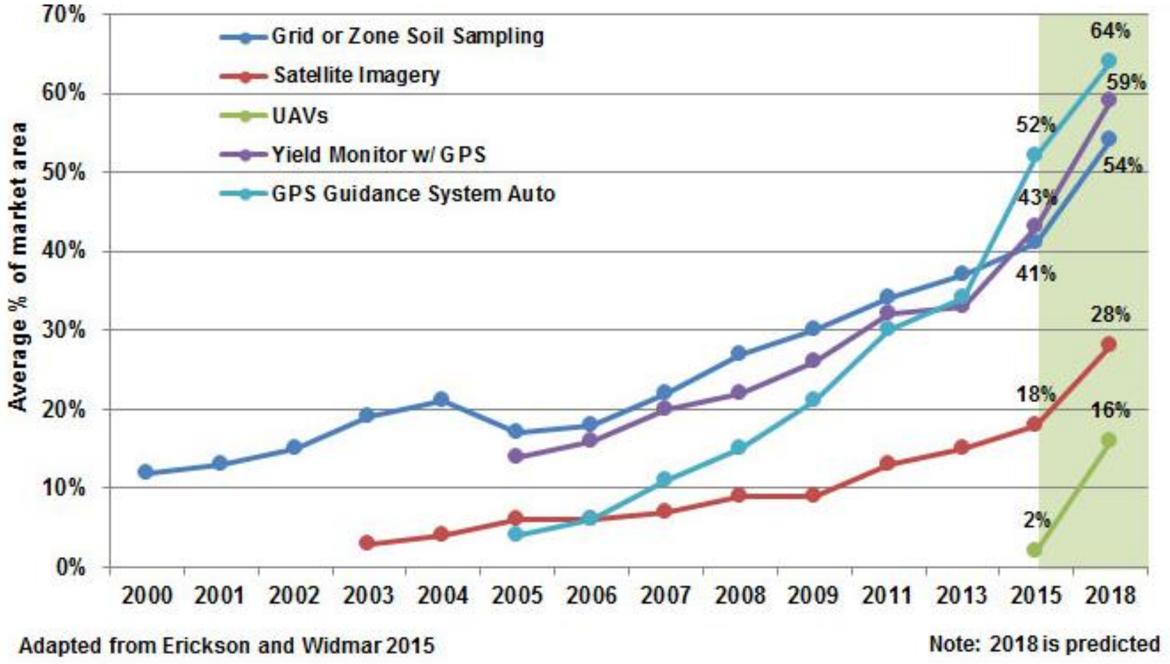

Figure 45 - Estimated Market Area Using Precision Services Over Time (Source: Farmdocdaily)[143]

EO data also enable farmers **to better select the crop area** depending on various indicators such as soil moisture or properties.

Regarding crop type and acreage mapping, information collected via EO programmes provides maps of cultivated areas from local to national level by the mid- or the end of the crop season to public authorities in order to monitor agricultural production on a regional or national scale. The combination of this data with other sources of data is used to delineate the cultivated area by crop type and emergence dates of the different cultures. EO data collected is also very useful to assess crop location changes in comparison with previous years in support of early warning for food security purposes. In addition, the spatial and temporal consistency over wide areas is a good indicator of favourable conditions for crops in each country.

EO data provides highly precise information in order **to respond to the requirements that are imposed on farmers by governments in the context of agricultural subsidies** provided by governmental authorities. In such cases, after having declared the crop type they will be harvesting to the public authorities, farmers need to perform controls on 5% of the surface area declared. VAS companies provide information on the crops in order to optimise the controls done for reporting purposes: the images provided limit the risks of these controls that are done by field inspections and increase their productivity.

EO is a **powerful tool to improve the understanding and management of water resources for agriculture**. Indeed, certain regions of the world lack the ground data to systematically evaluate the status of water bodies or are unable to develop effective measures to counteract the threat of water scarcity caused by population growth, climate variability, economic development, agriculture production or urbanisation. While increased pollution threatens lakes, rivers, estuaries, and groundwater bodies around the world, **EO offers independent, area wide, standardised, and long-term observations** to help address all of these challenges.[144] Several organisations provide information to monitor drought, and provide interactive maps and monthly drought bulletins that are then used by decision makers. These organisations include for example the US Agency for International Development (USAID) which publishes the Famine Early Warning Systems Network, the United Nations Food and Agriculture Organization (FAO) provides free of charge and publicly accessible global web maps. In addition, information related to land surface temperature is useful to monitor yield and droughts, in order to screen the impacts of climate change.

The figure below summarizes the main applications of EO data in agriculture.

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[143] *Farmdocdaily, 2015. Precision Agriculture: Not the same as big data but...[ONLINE] Available at: http://farmdocdaily.illinois.edu/2015/11/precision-agriculture-not-the-same-as-big-data.html [Accessed 30 May 2016].*

[144] *ESA, 2014. Earth observation support for the international fund for agricultural development.*

Type of applications	End users	Benefits
• Precision farming (Yield mapping Input management Farm management recording)	• Farmers • Agricultural cooperatives	• More efficient and appropriate use of agricultural inputs • Increased productivity
• Seasonal mapping of cultivated areas	• Public authorities (national, regional)	• Assess crop location changes • Better monitor food security issues
• Water management and drought monitoring	• Decision makers • National Public authorities • International bodies	• Prevention and improved monitoring of meteorological and hydrological drougts
• Support to subsidy controls	• Farmers (who perform the controls) • Public authorities (providing subsidies)	• More efficient controls • Reduction of the risks during the performance of controls

Figure 46 - Summary of main EO applications in Agriculture (Source: PwC-Strategy& analysis)

Market structure and trends

The EO market for agricultural-focused products is **rather fragmented**, even though the first applications based on EO data in the agricultural sector were developed in the 1990s. Indeed, many service providers develop products in niche sectors. As already mentioned in the section above, the most prominent agricultural sub-domain in which EO based products are developed is **precision farming**. Indeed, most of the service providers contacted during the course of the present study have indicated a focus on the development of products on very specific precision farming techniques (for example focusing on monitoring orchards dedicated to one or two types of fruit in a specific territory). The products provided are quite precise and user-friendly (some deliver comprehensive information on the state of the crops using colour codes, directly to farmers for example). However, as shown in the Figure 47, EO data is far from being the only source of data used for precision farming. An emerging trend is represented by the use of **drone-based imagery** to obtain very precise and high resolution images – which can potentially limit the possible added-value coming from the use of EO data.

A wide range of actors operate in the development of value added services: start-ups and SMEs, larger players such as Airbus geo-information services, pure scientific players such as research organisations and universities. In several cases **VAS companies partner with other specialised organisations** (research institutions focusing on very specific issues for example) in order to better understand the needs of the end users and potential clients. **A few large agricultural corporations have recently acquired or are in the process of acquiring VAS companies in order to benefit from their products directly and in-house**. As an example, Monsanto acquired the Climate Corporation, a company developing precision farming products, in 2013. This emerging trend limits the possibility of non-dedicated service providers to reach additional larger clients. Indeed, if this trend persists, large players will no longer resort to buying the services of VAS companies.

At the moment, the **type of clients** is as follows: **private actors** such as cooperatives or local relays and **representatives from the public sector** such as ministries. The need for public authorities to benefit from EO data in the agricultural sector is expected to grow in the coming years, with the rising pressure on agricultural resources on one hand and the growing number of regulations in the agricultural field on the other hand.

A certain number of SMEs and larger players currently lead projects in Africa, mainly funded by donors or international organisations and aim at **assisting public authorities in their decision-making processes in order to improve the monitoring of food security issues**. Most of these projects comprise a capacity building phase, directed towards local resources and aimed at guaranteeing the sustainability of the project on the long-term.

Opportunities in developing countries are expected to grow due to the pressing challenges related to food security. Indeed, as described above, EO data can potentially contribute to better monitoring and preventing droughts that can be particularly devastating in the context of food security issues. Several projects using EO data led by European VAS companies and funded by donors have been implemented in developing countries. These projects have increased the awareness of local actors regarding the benefits of EO data in this context. Several of the stakeholders interviewed have thus indicated that they forecast rising opportunities for VAS companies in this context.

Key Drivers	Key Obstacles
Opportunities are expected to rise in developing countries which are threatened by **food security** issues. As an example, EO data can contribute to monitoring the impacts of the "El Nino" phenomenon[145] which causes important droughts in several parts of the world.	**The emerging trend of large agricultural corporations acquiring small VAS companies** may limit the opportunities for service providers to reach out to this type of potential client.
The added value of EO data in the agricultural field is recognised internationally and implemented throughout wide scale initiatives such as **GEOGLAM**, which, thanks to the promotion of remote sensing tools in the agricultural sector contributes to the creation of potential opportunities for VAS companies.	Market needs are extremely specific to each application, terrain and type of agricultural products, thus requiring VAS companies to **partner with specialised organisations** in order to better understand the specificities of the end users.
Since the creation of the first applications in the agricultural sector in the 1990s, the **products now provided by service providers are quite elaborate and user friendly,** which can potentially drive new types of clients to show interest for such applications.	**High competition from other types of data such as drones,** for precision farming techniques based on EO data. There is an extensive need for **capacity building initiatives** in order to address the issue of a lack of local experts in developing countries, which currently hinders the ability of potential end users to understand the benefits of EO programmes.

Table 15 - Synthesis of key drivers and key obstacles on the EO market related to Agriculture (Source: PwC-STRATEGY& analysis)

Main players (examples) globally and in Europe

Airbus geo-information services, which is part of Airbus Defense and Space, develops applications based on EO data in 140 countries on a range of sectors: agriculture, forestry management, oil, gas mining and energy, land administration, etc. based on SPOT, Pléiades, TerraSAR-X and TanDEM-X satellites[146]. Airbus geo-information services has a leading precision farming application that was launched 15 years ago: the **FARMSTAR project**. Today, approximately 15,000 farmers are using the Farmstar application. The farming cooperatives which purchase this application can benefit from various solutions such as assessments, recommendations, preconisation statements, etc.

Many SMEs develop value-added applications based on EO data in the agricultural sector. GIM for example, a Belgian SME, uses Sentinel-2 data to develop specific smart farming applications. EFTAS, a German SME, has developed specific products to control farms' subsidy schemes in order to monitor huge areas. During the course of the present study, 9 companies of various sizes with products/services in agriculture have been consulted. Out of these 9 companies, 6 develop precision farming applications. All of them develop products and services in other fields as well (such as forestry), and 2 of them are or have led projects funded by large donors to monitor food security issues in Africa. The full list of companies engaged in consultation is reported in the Appendices.

One major actor in the field of EO related to agriculture was launched by the G20 in collaboration with the Agricultural Market Information System (AMIS) in 2011: the **Global agricultural geo-monitoring initiative (GEOGLAM)** aiming at coordinating satellite monitoring observation systems in various parts of the world. Its main objective is to "reinforce the international community's capacity to produce and disseminate relevant, timely

[145] The « El Nino » phenomenon first started off as being an annual weak warm ocean current that ran southward along the coast of Peru and Ecuador and became associated with the unusual large warming that occurred every few years and changed the local and regional ecology. Today, this phenomenon is known as having much larger consequences on wider geographical scale: it can have impacts in Latin America, Australia, South East Asia, Africa, and beyond. It has impacts on ocean temperatures, the speed and strength of ocean currents, the health of coastal fisheries

[146] Airbus Defence & Space. 2013. Smarter Decision Making with Premium Satellite Solutions. [ONLINE] Available at: http://www.intelligence-airbusds.com/files/pmedia/public/r33998_9_geo_003_geo-intelligence__en_low.pdf. [Accessed 6 June 2016].

and accurate forecasts of agricultural production at national, regional and global scales by using EO data"[147]. GEOGLAM is expected to provide AMIS with valuable information to enhance crop production projections and weather forecasting data[148].

Data flow along the value chain

The next subsections describe the main links in the EO data flow within the agriculture value chain.

Data collection and processing platforms

Service providers use two types of data to develop their applications and products: data from public satellites on one hand and data from private satellites on the other. Service providers currently use a large amount of Landsat data. Optical data is used to map different crop types while radar data is a very effective source of information to monitor specific crops such as rice crops in tropical areas which are characterised by very high cloud coverage. Satellites from private providers are also combined with Sentinel data: SPOT data, Rapideye data is for example used for VHR data (in order, for example, to develop precision farming products that focus on very precise fields) and Globview for verification purposes. Among the stakeholders interviewed (public and private), all of them have indicated currently using or have just started using Sentinel-1 & 2 data, and in most cases have started to develop precision farming applications. Service providers are planning on integrating Sentinel-3 data in order to benefit from mid-resolution data. Satellite data is then combined with in situ data, which are mainly field data and images from ground sensors. Field data is also used by several VAS companies to check the accuracy derived from EO judgments.

In terms of processing platforms, the **Copernicus Land Monitoring Service**, operational since 2012, provides geographical information on land cover and variables related for instance to the water cycle. The **Earth Observation Data Centre for Water Resources Monitoring** provides agricultural-related EO data, a range of tools supporting collaborative processes that VAS companies can benefit from and a certain number of specific applications which respond to specific needs.

Outsourced and in-house EO capabilities

Applications based on EO data related to agriculture were first initiated in the 1990s. Hence, VAS companies count a range of EO experts in addition to agronomists and several end users have been benefiting and using EO based applications for a long time. In addition, numerous VAS companies provide or propose, in addition to their applications, a specific assistance in order for the end users to be able to use the delivered services to their full potential.

Development of value-added software, products and applications

Service providers develop a wide range of products that have various forms: **maps or images of parcels of land** for example, which indicate via a colour code the risks that are detected (such as for example crop illness or a lack of irrigation on the portion of a crop that can be represented by a strong colour such as red), with information on, for example, the amount of water or fertiliser needed on a specific portion of the parcel and a list of indicators to help clients understand the information and support decision-making.

For example, the **project Sentinel-2 for Agriculture,** aimed at monitoring agricultural areas on a large scale, generates 4 added-value products: **images without clouds** produced on a monthly basis, **crop masks** which indicate where the cultivated fields are, **crop types** which identify automatically the dominant cultures in an area and the **Leaf Area Index (LAI)** which is a real time indicator of the level of vegetation.

In view of developing ever-more user friendly services, a growing number of service providers are building applications that are directly available on smartphones and/or tablets. Most of these applications currently provide information related to evapotranspiration, rainfall, irrigations on a defined area and a specific crop type.

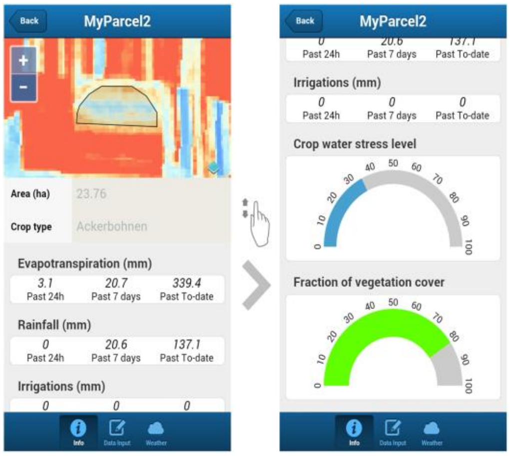

Figure 48 - Mobile application elaborated by the University of Natural Resources and Life Sciences in Vienna

[147] *GEOGLAM. 2016. About GEOGLAM. [ONLINE] Available at: https://www.earthobservations.org/geoglam_about.php. [Accessed 10 May 2016].*
[148] *ESA, 2014. Earth observation support for the international fund for agricultural development.*

In order to face the competition coming from other types of data, a rising number of service providers focus on niche sectors, which requires specific expertise. One significant example of a dedicated product in a niche sector which requires specific expertise on wine activities is represented by the activities carried out by Terranis, a spin-off of Airbus geo-intelligence. This micro-company has developed a specific **application for wine makers**: the objective of this service is to optimize wine harvest quantitatively and qualitatively. The application developed by Terranis provides information to the end users a few weeks before harvest in order for them to adapt their cultivation habits and thus produce wine of better quality.

End users

The users benefiting from value added services and products are both from the public and the private sector. In many cases, VAS companies provide specific training to the end users, which is adapted to the technical capabilities and needs of the clients. The training can, for example, consist of explaining to the end users how to interpret the maps and what types of decisions can be taken (i.e. increase irrigation on one portion of the field, or reduce the pulverization of inputs on another portion of the parcel).

On the private side of the user base, even though VAS companies develop specific products that mainly benefit **farmers**, these users can rarely purchase EO products directly because the cost of the service is relatively high. As an example, according to a cost-benefit analysis performed by the University of Natural Resources and Life Sciences in Vienna on satellite-based tools for irrigation management, one quarter of the farmers participating in the analysis indicated a willingness to pay EUR 3 per hectare[149]. Hence, **agricultural and industrial cooperatives** or **local relays** are most often the clients which then distribute the service within their network.

There is a wide variety of end users from the public sector: **ministries and other types of governmental bodies** and sometimes local authorities which need the information collected via EO programmes in order to obtain relevant information related to agriculture, such as seasonal maps of crops and acreages in order to assess crop location changes (as described in the sections above).

For projects related to food security issues in Africa, the main actors are **development agencies** (e.g. GIZ – German development agency), **donors** (e.g. World Bank and affiliated groups), **UN organisations** (e.g. World Food Programme, FAO), and **research centres**.

The following figure summarizes the data flow along the value chain for agriculture, from the acquisition of public and private data, to the processing of the data (how the processing of the data takes place and who performs it), and then to the development of the specific services.

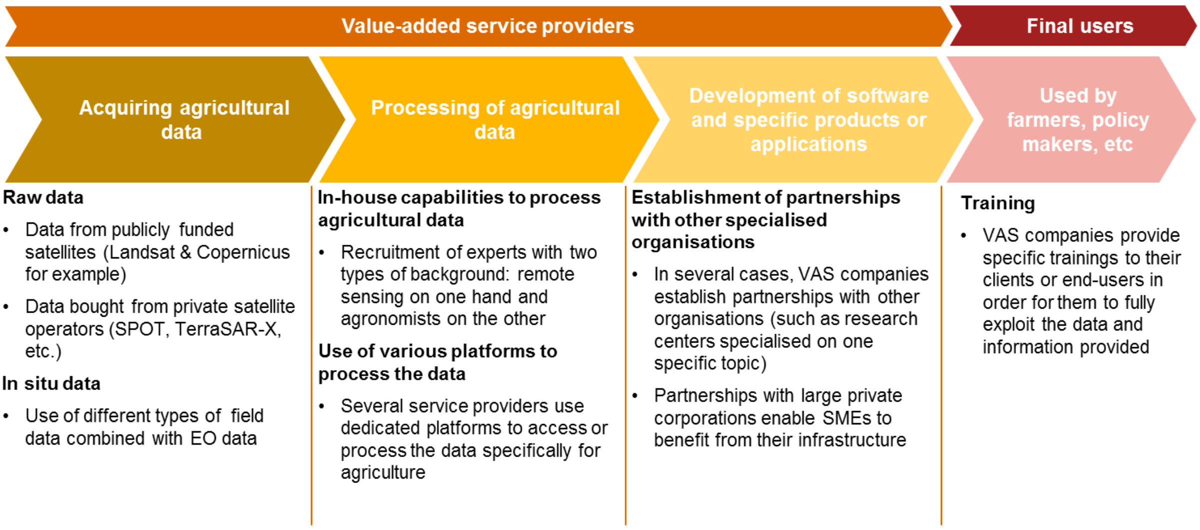

Figure 49 - Data flow along Agriculture value chain (source: PwC-Strategy& analysis)

Current role of Copernicus

As outlined in the above section, all stakeholders interviewed in the framework of this study have indicated that they currently use Copernicus data, and more specifically Sentinel-1 and 2 data. The portion of Copernicus data

[149] *Vuolo F, Essl L, Atzberger C. 2015. Costs and benefits of satellite-based tools for irrigation management.*

used in comparison with the overall EO data processed varies greatly among the stakeholders: from 10% to 70%[150]. This can be explained by the heterogeneity among the service providers as well as the recent availability of Copernicus data. Indeed, several private stakeholders are planning on integrating additional Sentinel data in the coming years.

Sentinel-1 and 2 data is used more particularly in order to develop precision farming applications. As an example, Sentinel-2 data provides very useful information in order for service providers to obtain reliable information on the amount of chlorophyll in the plants. Sentinel-2 data is also used by service providers because of its coverage and resolution: the 10-meter resolution enables service providers to develop field scale mapping. Its 5-day revisit time capability on the other hand is particularly useful to map monthly crop dynamics, especially in Africa. Indeed, **Sentinels data is also being used by private stakeholders leading projects in the African continent**, aimed at improving the monitoring of food security issues.

Sentinel data is however **very rarely the only source of data used**: most of the service providers have indicated combining Copernicus data with other sources of EO and in-situ data (such as ground based inspections). As an example, the service developed by GEOGLAM, 'crop monitor', combines Sentinel-2 with Landsat data in order to obtain accurate, timely and global information on crop conditions worldwide depending on crop types (such as wheat, rice, maize, soybeans, etc.).

Some of the stakeholders' interviewed have indicated that **they will be integrating Sentinel-3 data as soon as it becomes available** in order to perform monthly monitoring at country level. In this context, it should replace MERIS data, which provides information on vegetation with a medium-spectral resolution.

The Copernicus Land Core Services

The Copernicus Land Monitoring Service, operational since 2012, provides geographical information on land cover and on variables related, for instance, to the water cycle. It consists of three main components: a global component, which produces data across a wide range of biophysical variables describing the state of the vegetation, the energy budget and the water cycle; a pan-European component which produces 5 high resolution data sets describing the main land cover types; a local component, providing specific and more detailed information focusing on land cover and land used information. The European Commission has delegated the implementation of the Pan- European and local component to the European Environmental Agency (EEA) according to a 2014 Agreement.

Copernicus Land Service component	Name of the product	Detail
Global component	Normalized Difference Vegetation Index	Relates to vegetation and is adapted to coarse and medium resolution
Global component	Land Surface Temperature	Relates to Energy budget and is adapted to a coarse resolution and provides information related to the radiative skin temperature of ground.
Global component	Soil Water Index	Relates to water and quantifies the moisture condition at various depths in the soil and is mainly driven by the precipitation via the process of infiltration.
Pan- European	European Settlement Map	The European Settlement Map is a spatial raster dataset that is mapping human settlements in Europe based on SPOT5 and SPOT6 satellite imagery. It is published with two associated data layers.
Local	Urban atlas	The Urban Atlas is providing pan-European comparable land use and land cover data for Large Urban Zones with more than 100.000 inhabitants as defined by the Urban Audit.

Table 16 - Main products from Copernicus services in Agriculture (Source: land.copernicus.eu)

Role of Copernicus in the context of food security issues in Africa

[150] *Source: stakeholders consultation*

Copernicus data and cores services are of significant added-value in order to better monitor food security issues in the African continent. Indeed, while the demand for agricultural products continues to grow, there is an increased pressure on resources, leading to mounting challenges jeopardising food security. Food security can be defined as a situation when all people at all times have both physical and economic access to sufficient food to meet their dietary needs for a productive and healthy life. Food security is at the top of list of the Millennium Development Goals (MDGs) with an objective of eradicating poverty and hunger throughout the world. More than 60 countries have made considerable progress towards achieving this objective.

As an example, the use of Copernicus Global Land products in combination with field work has enabled the President of Botswana to officially declare a drought at national level in 2015. In this context, one specific project was conducted by a German SME, EFTAS, in Sudan, in order to improve the monitoring of food security in the country. The "Global Monitoring for Food Security" (GMFS) programme, which is part of ESA's contribution to the GMES programme, has two main objectives: (1) establish a platform to provide operational Geo-information services for crop monitoring and (2) serve policy makers and operational users sustainably.

Sudan, with a surface area of 1.88 million square km and a population of 2.8 million, is one of the largest countries in Africa. In many African countries, including Sudan, information on annually cultivated land is not available. Cultivated land contains the major annual rain fed crops in Sudan such as Sorghum, Millet, and Sesame. Because of the specific climate conditions in the Sahel with extremely irregular and seasonally and geographically varying rainfalls, the Sudanese region is characterised by unstable and unpredictable growing seasons. The large variations of the precipitations cause high vulnerability of certain Sudanese populations in the areas depending on rain fed agriculture.

In this context, the Federal Ministry of Agriculture and Irrigation (FMoAI) of Sudan has called upon the GMFS partnership to integrate Earth Observation (EO) technologies in order to better improve and strengthen the agricultural monitoring framework in Sudan and in particular obtain more reliable data on traditional rain fed areas. More specifically, the objective was to utilize satellite data to optimise the statistical sampling and to better allocate their resources and obtain more accurate results.

The cooperation between the FMoAI and the GMFS partnership took place between 2007 and 2013. Over this time period, the main services developed were:

- An **early warning component to monitor crop** conditions in order to have regular information about the distribution of overall vegetation and potential agricultural production during the growing season,
- A **mapping of cultivated area** using high resolution remote sensing.

Finally, the ultimate objective of this project was the **strategic know-how transfer to build capacity** within the FMoAI in order for the tools developed to be used sustainably in the long term and to be transformed into actual workflows. The results contributed to the establishment of a GIS & Remote Sensing Unit, currently composed of two experts, under the Agricultural Statistics department of the General Administration of Planning and Agricultural Economics of the FMoAI, which has since then taken over the processing of products and routines implemented in GMFS.

In 2012, the cereal harvest for the Republic of Sudan was estimated at 2.773 million tonnes, among which 2.089 million tonnes of sorghum, 0.365 million tonnes of pearl millet, and a low wheat harvest of 0.324 million tonnes.[151] In Sudan, the agricultural sector accounted for 29.2% of the Gross Domestic Product (GDP) in 2014, which makes it the main non-oil contributor to GDP. In 2012, according to the FAO, agriculture was the main source of foreign exchange earnings, prior to the rise of oil[152]. About 70% of the harvested cereals are cultivated in rain fed agriculture and depend on the seasonal rains. In this context, the establishment of the EO products have a significant added value on monitoring droughts in order to prevent food security issues.

The process chains and routines developed by EFTAS, a German SME, under the GMFS initiative are designed to process and integrate Sentinel data as soon as it is available on site. The projected impacts have been quantified and identified considering that Sentinel data is easily accessible on site.

151 Alemu Asfaw, FAO. 2012. QUASI CROP AND FOOD SUPPLY ASSESSMENT MISSION TO SUDAN. [ONLINE] Available at: http://www.fao.org/sudanfoodsecurity. [Accessed 24 May 2016].
152 Alemu Asfaw, FAO. 2012. QUASI CROP AND FOOD SUPPLY ASSESSMENT MISSION TO SUDAN. [ONLINE] Available at: http://www.fao.org/sudanfoodsecurity. [Accessed 24 May 2016].

The integration of Sentinel data should result in a significant improvement of the quality of EO products for agricultural applications. Regarding the service providing monthly monitoring of vegetation dynamics for example, Sentinel-3 data improves the spatial resolution by a factor of three, from 1 km to 300m, and allows **a much sharper differentiation between agricultural land, natural vegetation and unvegetated desert areas.** Concerning the application related to seasonal crop mapping, **Sentinel-1 and 2 should considerably enhance the processing of cultivated land and crop maps with a high temporal profile**, covering the whole of Sudan and being comparable between seasons. Without reliable access to adequate and free data that task has not yet been fully implemented, but is **expected to become feasible with Copernicus satellite data.** In addition, the use of these Sentinel data should have an impact on the productivity in-house of the GIS and Remote Sensing Unit within the FMoAI, even though it is at this stage difficult to quantify the exact projected impact.

In the long run, it is very likely that the use of Copernicus space component data will enable the FMoAI to **improve its internal organisation** and thus **identify specific tasks to outsource to private local companies**, considering that the appropriate funds are available. Using Sentinel data should also contribute to the **creation of knowledge and raising awareness on the potential benefit of EO data in the agricultural field**. Considering the importance and high potential of agriculture in Sudan and the fact that agriculture provides jobs to approximately 70 to 80% of the labour force in rural areas, the impact should be significant.

The **strong political will of high-level decision makers in Sudan** contributes to promoting the use of EO data in other sectors beyond agriculture: on environmental issues for example or in the forestry sector. Additionally, the Action Document for the GMES and Africa Support Programme was recently adopted by the EU in 2015. Its objective is to improve capacities of African policy-makers and planners to design, implement and monitor national, regional and continental policies to promote sustainable management of natural resources using EO data[153]. Hence, it is quite likely that Copernicus space component data will be further promoted and used within the agricultural sector in Sudan in order to better monitor food security issues.

Copernicus socio-economic impact assessment

The identification of the socio-economic impacts of the Copernicus programme within this study was performed through stakeholder consultation, based on one-to-one interviews with a sample of European stakeholders from the agricultural value chain: six private companies of different sizes, one international organisation, one research centre and one regional network.

Copernicus current enabled revenues

The results of our study and afferent analysis has shown that the Copernicus programme has an impact – yet limited and not entirely optimised – on the revenues of public and private stakeholders developing applications based on EO in the agricultural sector.

Considering the fact that a majority of the VAS companies developing applications based on EO data focus on precision farming services, and that precision farming applications represent approximately 93.30% of the revenues generated by EO service in the agricultural sector[154], the quantitative analysis of the Copernicus current enabled revenues will be done on this specific sector. In 2015, the global precision farming market was valued at USD 2.76 Billion (EUR 2. 46 billion)[155]. According to the Technavio geographical distribution, the European market for precision farming accounts for approximately EUR 368 Million (15% of the global market). Satellite imagery technologies which accounted, in 2015, for 18% of the total market, would amount to EUR 66.37 Million. According to the stakeholders' consultations, Copernicus data represents approximately 13.87% of the total EO data used by intermediate users. Thus, **the total current Copernicus enabled revenues for European VAS operating in the precision farming sector is of approximately EUR 9.21 Million (minimal estimation) corresponding to 13.89% of the total revenues of the EO downstream market for precision farming.**

With the provision of free and more precise data, service providers are able to not only improve the precision and accuracy of their existing applications by approximately 20% and thus provide a better offer to their clients,[156] but also to develop additional ones. As an example, some VAS companies focusing on projects taking place in the

153 European Union. 2015. Action Document for the GMES and Africa Support Programme. [ONLINE] Available at: https://ec.europa.eu/europeaid/sites/devco/files/annex-8-gmes_en_0.pdf. [Accessed 24 May 2016].

154 Source : PwC & STRATEGY& analysis

155 Marketsandmarkets. 2016. Precision Farming Market worth 4.80 Billion USD by 2020. [ONLINE] Available at: http://www.marketsandmarkets.com/Market-Reports/precision-farming-market-1243.html. [Accessed 14 June 2016].

156 This approximation was calculated in the framework of the stakeholders' consultation and the online survey and is a result of their quantitative responses regarding the impact of Sentinel data on the quality of their products.

African continent lacked sufficient data in order to develop highly qualitative applications. The precision of the biophysical data provided by Sentinel-2 on the level of chlorophyll of a plant enables service providers to provide an improved service to their clients. More specifically, Copernicus data seems to have an increased added-value for projects taking place in Europe and Africa in comparison with services developed for end users based in North America. Indeed, one of the stakeholder's interviewed has indicated that Landsat data is used preferably to Sentinel data over these regions.

Stakeholders interviewed have declared that Copernicus data has enabled them to **boost their sales moderately**. In many cases, the Copernicus programme has led to **job creation** in SMEs. As an example, one of the start-ups interviewed increased the number of its experts from 3 to 12 in over a year.

Regarding the quantitative impacts for the end users, the Copernicus programme has had **positive impacts on the productivity of farmers benefiting from EO-based applications**. Several of the respondents developing precision farming applications have indicated that the farmers using their products benefit from an increased productivity of approximately 20%. Similarly, one start-up currently developing a precision farming product is testing the applications with a sample of 17 farmers which have indicated that using the application has enabled them to **save approximately 20% in terms of water resources**. One other specific application developed by a British SME providing information on crop productivity (identifying issues in the field with regards to soil cover, biomass, crop stress, crop damage, etc.) has allowed farmers to **optimize yields by approximately 5%**.

Non-monetary benefits of Copernicus

The network effects derived from the Copernicus programme are important for service providers. Indeed, participation in specialised workshops and conferences on agriculture-related topics organised by ESA or the European Commission offer **precious opportunities to young start-ups and SMEs in order for them to build partnerships**.

The products and services provided by VAS companies, based on Copernicus data, intrinsically have a positive impact on the environment since they enable farmers to **use the appropriate amount of agricultural inputs (e.g. fertilisers and pesticides)** at a more precise and defined location. However, environmental impacts are not yet a top priority for stakeholders from the agricultural sector.

In terms of social impacts, an optimised use of agricultural inputs thanks to more accurate precision farming techniques enables farmers to **harvest food which is less detrimental to human health**. They can prevent diseases on crops for example and limit the amount of inputs used that may have a limited but real impact on human health.

Copernicus projected contribution to the global and European socio-economic impacts

(M EUROS)	Precision farming market	EO downstream market for precision farming	% of Copernicus enabled revenues	Copernicus downstream revenues for precision farming (minimal estimation)
2015	368	66.30	13.89%	9.21
2020	641	221	17%	37.70

Table 17 - Comparison of the current and prospective enabled revenues directly attributable to Copernicus from 2015 to 2020 (Source: PwC- Strategy & analysis)

The contribution of Copernicus to overall enabled revenues is expected to rise in the coming 5 to 10 years – not only are most of the stakeholders planning on integrating a larger portion of Copernicus data within the overall EO data processed, but also because most applications based on Copernicus data were at an initial phase at the time of the study. The estimation of the projected contribution of Copernicus enabled revenues for European service providers will be limited since only 50% of the stakeholders' interviewed have been able to quantify it.

The method used to quantify the projected contribution of Copernicus on overall precision farming revenues will be identical to the one applied to quantify the current enabled revenues. Thus, according to our analysis, the revenues generated from the European precision farming market are expected to reach **EUR 641 million** in 2020 (with global revenues for the precision farming market of EUR 4.28 Billion). Considering that the market share of satellite imagery in the precision farming sector increases at a regular pace, it **would represent 34.60% of the market in 2020, which corresponds to EUR 221 Million.** In parallel, the revenues directly attributable to Copernicus should increase and **reach approximately 17% of the service providers' overall revenues in 2020, corresponding to EUR 37.70 Million (minimal estimation).**

In order to provide a high estimate of the total revenues directly attributable to Copernicus, the analysis was performed on the basis of the GIS market. For methodological purposes, the shares attributable to the EO downstream market were considered as being similar for the GIS market. In 2015, the revenues of the GIS market directly attributable to Copernicus is estimated to be of approximately EUR 13.69 million, slightly above the minimal estimation. In order to obtain a high estimate for 2020, since EARSC does not provide the evolution of the portion of the applications related to agriculture against the total amount of applications, the methodology chosen was to take into account the fact that the European GIS market for 2015 corresponded to 2.08 times the EO market for 2015. Hence the GIS revenues for precision farming applications are estimated to be EUR 460.28 million in 2020, with Copernicus downstream revenues estimated to be **EUR 78.24 Million**, corresponding to more than double of the minimal estimation.

(M EUROS)	Overall GIS market for agriculture	GIS revenues for precision farming applications	% of Copernicus enabled revenues	Copernicus downstream revenues for precision farming (high estimation)
2015	105.65	98.58	13.89%	13.69
2020	493.33	460.28	17%	78.24

Table 18: Comparison of the current and prospective enabled revenues directly attributable to Copernicus for precision farming (Source: Technavio, PwC - Strategy& analysis)

The figure below provides an overview of the potential increase of the Copernicus enabled revenues over 2015-20. The reader should focus on the minimal estimation which brings a conservative and robust estimation. Considering that a limited portion of the stakeholders were able to quantify the projected enabled revenues from Copernicus, the actual value of the market might be higher than the minimal estimation for 2020.

The incorporation of EO data will enable service providers to **improve the quality of their existing products.** Indeed, the higher revisit time, the appropriate resolution spectral variety (e.g. the additional spectral bands will enable users to calculate more precisely the quantity of chlorophyll in the vegetation) will give additional opportunities to service providers who will push their business model forward.

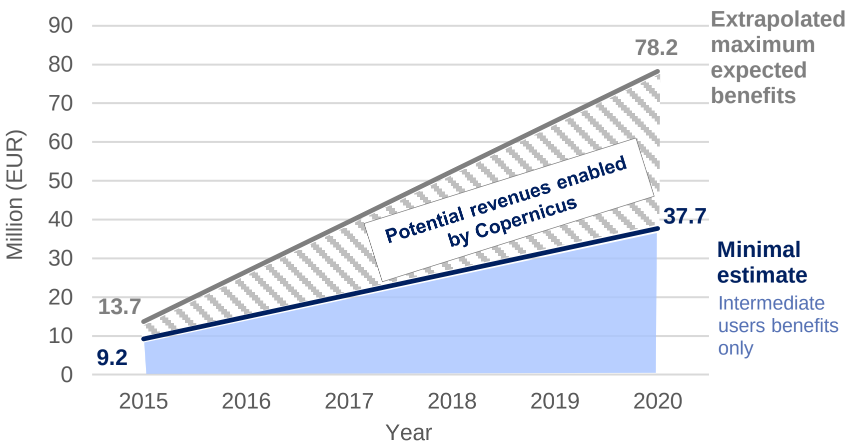

Figure 50 - Current and prospective enabled revenues by the availability of Copernicus data in Europe for precision farming (Source: PwC-Strategy& analysis)

Over the period 2015 – 2020, Copernicus-enabled revenues in the agriculture value chain are forecasted to support a cumulated total estimated at **between 1080 and 2120 person years** within the EO and GIS downstream markets across Europe.

It is assumed that productivity among the intermediate users was the same as for the industries NACE 62.01 and 62.02. The enabled employment estimation method used employment, turnover and GVA data from the Eurostat Structural Business Statistics. The 2020 estimates were based on E3ME growth projections for these variables.

Economic	• **The average share of the overall revenues of service providers directly attributable to Copernicus was approximately 13.89% (minimal estimation) in 2015 and could reach 17% in 2020[157].** • **With Sentinel data, VAS companies improve the precision and accuracy of existing products by approximately 20%[158].** • **Copernicus data in the agricultural field has led to moderate job creation.** • **Thanks to applications based on Sentinel data developed by VAS companies, farmers increase their productivity by a more efficient and appropriate use of agricultural inputs (up to 20% for one application[159]).** • **Thanks to higher revisit times, and appropriate resolution spectral variety, Copernicus data should create additional business opportunities and enable service providers to boost their sales additionally (expected)**

Social	• **The organisation of specialised conferences and events on agricultural-related topics are of significant added value for young start-ups to build their networks.** • **Precision farming applications based on Sentinel-2 data enable farmers to produce food of better quality and less detrimental for human health.**

Environmental	• **Precision farming services reduce the potential negative impact of agriculture on the environment by enabling a more efficient and appropriate use of inputs.**

[157] *Source : stakeholders consultation*
[158] *Source : stakeholders consultation*
[159] *Source : stakeholders consultation*

CASE STUDY

Improving irrigation management via EO data in Lower Austria

Context: the agricultural sector in Austria

The agricultural area, including alpine postures, account for approximately **38.4% of its total territory of 83 871 square kilometres**[160]. Agricultural activities, which account for approximately 2% (2015) of the country's GDP and 4.8% of the country's total employment, are concentrated in the eastern and north-eastern parts of the country.

A **number of different actors are involved in the Austrian agricultural policy**, including the Federal Ministry of Agriculture, Forestry, Environment and Water Management which is in charge of the harmonisation of the agricultural policy within the framework of the Common Agricultural Policy, of the attribution of the governmental subsidies, of market organisation, agriculture extension, etc. The agricultural departments of the nine provincial governments of Austria handle the implementation of support measures for agricultural and forestry enterprises. The interests of all Austrian farmers are represented by so called "Chambers of Agriculture" which are coordinated by the Austrian Chamber of Agriculture. Their main task is to give advice to farmers and conduct tasks that are requested by national and local governments. The market organisation Agrarmarkt Austria (AMA) was founded in 1993 to execute market regulations and carry out agricultural marketing throughout the country. The Austrian Agency for Health and Food Safety conducts various types of investigations related to food safety in order to prevent infectious diseases in humans. Finally, the Federal Environment Agency has a specific working group focusing on agriculture which contributes to the environmental assessment of agricultural activities. Its key added value relies in the agro-environmental indicators for assessing the relations between agriculture and the environment.

In this context, the **region of Marchfeld in the northern part of the country suffers from a sound water resource management issue**. Indeed, due to the shortage of precipitation and the semi-arid regional climate, farmers began to intensify crop production by irrigation with groundwater. Hence, most of the cultivated land in Marchfeld is equipped with irrigation infrastructures, which supplies simultaneously urban and industrial sectors. **Irrigation water accounts for up to 60% of the total freshwater use in this region** and is particularly important during the cropping periods for specific crops (such as sugarbeet, potatoes and various other vegetables) and during the dry periods for semi-intensive crops (i.e. cereals and oilseed). With a growing demand of high quality food, sustainable local production and market development strategies enhance the need for tools for more efficient and organised irrigation management.

The Institute of Surveying, Remote Sensing and Land Information from the University of Natural Resources and Life Sciences of Vienna therefore conducted a demonstration campaign from May to September 2013 in the Marchfeld region, on an area of approximately 60,000 hectares in order to improve irrigation management techniques.

The key specificity of this project relies in its particular approach: GIS and remote sensing experts from the Institute of Surveying, Remote Sensing and Land Information have taken the decision to **target the Austrian farmers directly**, and not agricultural cooperatives, as do most of the service providers. Indeed, even though this innovative and particular approach is more time-consuming and challenging, the analysis has shown that **establishing contact with the farmers directly is more efficient in order for the service provider** to better respond to the users' needs and to assess the usefulness of the application (in terms of type of information they need and how it should be delivered in order to be as practical as possible).

Developing a service to assess crop water requirements based on satellite imagery

This campaign took place in several steps: firstly, the stakeholders compared the irrigation volumes estimated

[160] *CIA World Factbook. 2016. The World Factbook. [ONLINE] Available at: https://www.cia.gov/library/publications/the-world-factbook/geos/au.html. [Accessed 15 June 2016].*

from satellite and the irrigation supplied by the farmers in order to deduct the efficiency of water use. Then, during and after the irrigation season analysed, they proceeded to an assessment of the service with the users, based on questionnaires and specific interviews which enabled the stakeholders to understand the extent of the information's usefulness.

The model developed by the Institute of Surveying, Remote Sensing and Land Information calculates crop evapotranspiration (ET) using daily values of main agro-meteorological variables such as temperature, solar radiation, wind speed and air humidity which is provided by local weather stations. The crop water requirements (CWR) is calculated by subtracting the rainfall from crop ET. If needed, the CWR can be further processed using additional temporal and spatial scales.

The most challenging aspect in the data processing chain encountered by the project stakeholders was their **ability to acquire successfully cloud-free satellite images**. Indeed, the area of interest (i.e. the Marchfeld region) is located in the overlapping area between two Landsat orbits within which Landsat manages to attain a revisit time of 8 days, which is usually not sufficient to produce cloud-free scenes.

Hence, the project was elaborated in view of an upcoming availability of free satellite sensor data and in particular in view of Sentinel-2 data. Indeed, when the analysis was first performed, the project stakeholders took into account the fact that Sentinel- 2 satellites, once launched and operational, would be able to acquire cloud-free images every 5 days in areas with clear-sky conditions in summer, and every 15-30 days in cloudy areas. According to the analysis performed, GIS experts noted that for the Marchfeld region, cloud-free images would be available every 10 to 15 days. In addition, the remote sensing experts have stated that the combination of Sentinel-2 and Landsat-8 data would further increase the opportunities to acquire cloud-free scenes. In the meantime, the information has been derived from commercial satellite data such as DEIMOS-1 in complement of Landsat 8.

The institute then ensured that the format of the product was easy-to-use, reliable and correctly embedded into the irrigation routine operations of farmers. After having reviewed the different possible options, a webGIS solution (an extract is available in the following figure) already implemented in past projects in similar contexts, was chosen. The specific irrigation information and advice was published at a regular pace, and the participating farmers had a restricted access to the information available on their specific parcels.

Overall, the service delivered the following specific services: **crop development maps** available every 7 to 10 days guaranteed with a spatial resolution from 10 to 20 meter, **evapotranspiration map and information and weather data and forecast** delivered daily and finally **specific irrigation requirements depending on crop types**. The Institute of Surveying, Remote Sensing and Land Information also provides customer support and training to the farmers if needed.

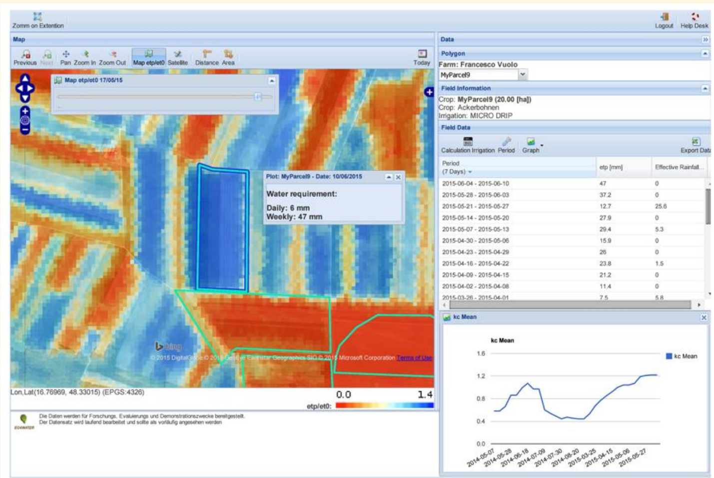

Figure 51 - Extract of the webGIS information used to deliver the information to farmers (Source: Institute of Surveying, Remote Sensing and Land Information)

Copernicus prospective enabled revenues

As a result of the demonstration campaign, a total of 358 irrigation units were registered into the webGIS system, amounting to a total of approximately 2000 hectares, which corresponds to 3.3% of the total area of the targeted region. In addition, 30 farmers provided feedback on the usefulness of the project, in one way or another.

The results of the assessment showed **very different irrigation levels depending on crop types**. For example, sugar beets received less water than the potential requirements according to the results while carrots, spinach and peas received more water than required. In general, the data indicated that the service could enable potential economic benefits due to more efficient irrigation methods.

This service has also shown potential economic benefits for the end users. Among the 30 farmers interviewed, 23% declared that they did not foresee any margins for economic optimization. **50% have however declared that further improvements could be achieved by optimizing the total amount of water requirements** as well as by optimising the distribution of individual irrigation events. The assessment showed that farmers had quite a positive interest in the service. Indeed, **54% of the farmers interviewed expressed a general willingness to pay, directly, or via cost sharing, for such a service**.

Improved irrigation management can have important economic impacts. The running costs for irrigation vary between around EUR 0.1-0.2 per cubic meter for irrigation systems powered by electricity to around EUR 0.3-0.5 per cubic meter for diesel systems. Considering that a farmer irrigates up to 2000 cubic meter per hectare in a year, irrigation cost would range between EUR 400 and EUR 1000 per hectare. If we take into account the fact that the entire region of Marchfeld is irrigated (40,000 ha), **the total irrigation cost for one year would range between EUR 8 Million and 20 Million**.[161]

By downscaling the data applicable to Austria country wise, we can consider that around half of the farms (49%) have less than 10 hectares of agricultural area and cover around 10% of the region's total area, whereas the other half (51%) are farms of more than 10 hectares, which account for around 90% of the region's total area. Hence, half of the farmers encounter irrigation costs ranging between EUR 3,600 and EUR 9,000[162] (and less) yearly, and the other half pay between EUR 4,400 and EUR 1,100 (minimal estimation)[163].

In parallel, an analysis of the cost of the service per hectare per year was performed in order to quantify the potential economic benefit of the integration of Sentinel data instead of commercial satellite data. Two types of costs can be identified: variable costs (that may change depending on the number of hectares and users) and fixed costs comprise the operative costs and the satellite data acquisition and processing. The calculation of operative costs was done by taking into account three categories: personnel-effort for the satellite processing chain (EO data procurement, atmospheric correction and generation of products, quality control, etc.); satellite data in itself, with its costs depending on the type of data needed, the coverage and the resolution. For this specific case, the analysis was done on four different cost scenarios, as depicted in the following figure.

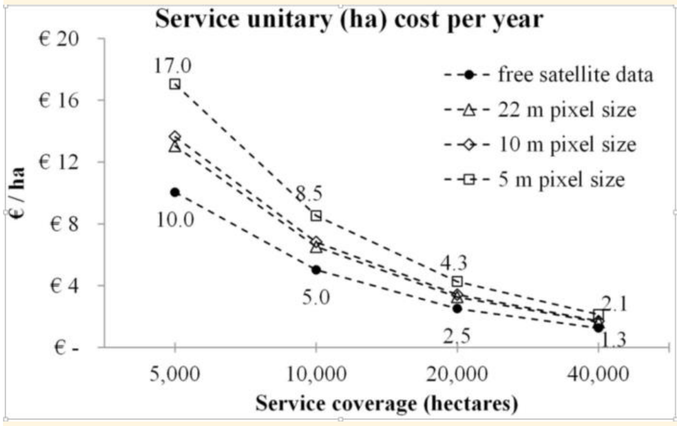

Figure 52 - Service cost per hectare for one growing season

According to the analysis performed, the integration of Sentinel data in this specific irrigation management product will enable a **significant cost reduction of the images**. Indeed, the cost of the data needed to cover the specificities of this region and length of the irrigation season (which requires a minimum of 10 images) would range between **EUR 15,000 (DEIMOS-1) and EUR 35,000 (RapidEye)**. The availability of Landsat-8 and Sentinel-2 data would however greatly reduce the need to resort to commercial data.

Using commercial satellite data at approximately 10-30 metres pixel size, the total service cost would range between **EUR 65,000 and EUR 68,000 per growing season**. The cost of the satellite data is expected to comprise between 25% and 40% of the total cost of the service (the portion of data cost is higher in cases when VHR data is needed)[164]. **With**

[161] *Source : Institute of Surveying, Remote Sensing and Land Information & Pwc- Strategy& analysis*
[162] *Considering that farms of less than 10 hectares are of 9 hectares and less*
[163] *Considering that farms of more than 10 hectares are of 11 hectares and more.*
[164] *Vuolo F, Essl L, Atzberger C. 2015. Costs and benefits of satellite-based tools for irrigation management.*

the availability of Sentinel-2 data, the average service cost is estimated to be of approximately EUR 50,000 per growing season[165] meaning a reduction of **23% to 26.40% of the total service cost.**

Hence, by bringing down the cost of the total growing season to a price/hectare per year, **the service, if based on Sentinel-2 data, would have a cost of approximately EUR 1.25 per hectare per year** (considering that the total area of the Marchfeld region of 40,000 hectares is irrigated), **whereas it would range between EUR 2.5 and EUR 4.3 per hectare per year with commercial data**. Indeed, because of the cost of the service, only the regularly irrigated part of Marchfeld (i.e. 20,000 hectares) could be covered. As outlined above, a portion of the farmers expressed a general willingness to pay and, according to the survey performed by the Institute of Surveying, Remote Sensing and Land Information, they would be willing to pay between EUR 3 to EUR 5 per hectare per year. Hence, by integrating Sentinel data, the price of the service would be significantly below this price range, which might attract additional end users to pay for it.

In 2015, the service provider in charge of leading this project has spent approximately EUR 20,000 on the acquisition of commercial satellite data. The gradual integration of Sentinel-2 data will enable the project stakeholder to reduce the budget dedicated to data acquisition and invest it in other activities such as Research & Development projects in order to launch new applications, elaborating technical support programmes to increase the value added of the services provided, etc.

The specific approach of the project stakeholders, which is to target individual farmers directly instead of intermediaries (such as farming cooperatives) poses one specific challenge for the application to be successful and economically viable. Indeed, outreach to individual farmers requires an extensive amount of time and resources. An individual relationship with each individual farmer needs to be established in order to ensure trust and to convince them of the added value of the proposed product, which implies considerable investment. The ultimate objective of the Institute of Surveying, Remote Sensing and Land Information of Vienna is to create a critical mass and then create a development cooperative.

[165] *Vuolo F, Essl L, Atzberger C. 2015. Costs and benefits of satellite-based tools for irrigation management.*

Voice of Copernicus' users: SWOT [166]

STRENGHTS

- The availability and reliability of Copernicus data enables service providers to develop ever-more reliable and qualitative agricultural products that are user friendly.
- Copernicus-related events organised by the EC or ESA have demonstrated their usefulness in order to build networks and create new partnerships in the agricultural field.
- The products developed based on Copernicus data are very functional and can be easily adapted to different scales and user needs.

OPPORTUNITIES

- Due to the economic and environmental conditions in the agricultural sector that put pressure on natural resources, the recourse to EO data is becoming increasingly necessary, especially in the public sector in order to prevent and monitor food security issues.
- The Copernicus programme has increased awareness of the need to use EO data for agricultural end users, which will create new opportunities for service providers.
- The variety of EO products in the agricultural sector enables users to address many sub-sectors such as precision farming techniques, water management techniques, larger scale products directed toward public authorities, etc.

WEAKNESSES

- Topics addressed by the Copernicus Land Monitoring Services are too limited and do not address all the users' needs.
- Start-ups in the agricultural sector lack funding to ensure sustainability of their activities.
- There is a lack of communication between service providers and end users (especially farmers), causing a limited knowledge of their specific needs.
- The issues linked to access to data in view of developing agricultural related products have negative impacts on the efficiency and productivity of the services providers.
- VAS companies encounter difficulties in establishing contact with local relays (such as agricultural cooperatives) to ensure sustainability of product usage.
- Service providers developing precision farming products experience difficulties to showcase precisely the ratio cost/benefits in order to better

THREATS

- VAS companies which develop agricultural-related applications based on Copernicus data need to indicate a matched investment in terms of human resources or infrastructure in order to be able to access the data.
- With the market of agricultural related EO products being fragmented and yet insufficiently mature, in order to stay competitive, companies have to continuously develop their products and propose ever more innovative solutions.
- Difficult weather conditions sometimes hinder the capacity of satellites to extract agricultural related data.
- The impossibility for end users (in this case farmers) to afford precision farming techniques limits the possibilities of service providers.

[166] *PwC-Strategy& analysis, on the basis of interviews conducted in 2016 (cf detailed list of interviewees in the Appendices). Please also refer to the specific SWOT related to EO products in developing countries and more specifically on the African continent in the Appendices*

Policy recommendations to foster Agriculture through Copernicus

Strategic pillar	Sectoral recommendations for policy action	Priority level
***Pillar I*: Ensure access to data**	***#AGR-1 – Facilitate access to data at a national, regional and local level in developing countries*** There is a strong need to develop and ensure understanding and access of EO data in order for the information extracted to be exploitable and useful to all users and be exploited at best. Thus, the launch of **capacity building campaigns coupled with a facilitated access to data** in developing countries could have a significant impact on driving the attention of potential users.	2
***Pillar II*: Support innovation**	***#AGR-2 – Boost synergies between service providers and potential agricultural end users in Africa throughout the implication of NGOs and international organisations*** In order to facilitate the outreach to potential end users in Africa, intermediate users and/or the EC should involve local NGOs and international organisations (such as the World Food Programme) in order for them to act as local relays towards end users and hence boost synergies service providers and end users in this region of the world.	1
***Pillar II*: Support innovation**	***#AGR-3 – Create specialised networks on EO products related to agriculture*** Service providers often encounter difficulties to reach potential clients. In order to boost their businesses, public authorities could envisage **creating a network of SMEs who develop agricultural applications** to establish contact between the potential clients and the companies that provide the required service.	2
***Pillar III*: Increase awareness and use**	***#AGR-4 – Launch training campaigns in order to increase the awareness of end users from the agricultural sector*** **Increase awareness of end users from the agricultural** sector (especially farmers) by, for example, organising training sessions in order to showcase the potential added-value of EO data in order to increase the productivity of farmers.	1

Specific recommendations linked to food security issues in developing countries

***Pillar I*: Ensure access to data**	***#AGR-5 – Establish the appropriate infrastructure to ensure access to EO data*** **Access to data is a major challenge in developing countries – without the proper infrastructure, it will be impossible to develop sustainable EO projects. In order for EO-based agriculture products to expand in Africa, significant efforts to set up reliable infrastructure are necessary, driven by a sound political commitment from both local and international authorities to develop the appropriate capacities to support the development of these technologies.**	1
***Pillar I*: Ensure access to data**	***#AGR-6 – Increase capacity building initiatives for agricultural end users in order to ensure access, analysis and use of EO data*** Regarding projects taking place in developing countries, the Copernicus programme should set a high priority on **capacity building initiatives of agricultural end users to access, analyse and exploit data collected via EO programmes**. Indeed, know-how transfers are necessary to ensure sustainability of the programmes.	1
***Pillar II*: Support innovation**	***#AGR-7 – Envisage a regionalisation of EO products developed by VAS companies in order to respond simultaneously to identical challenges*** Regarding food security issues, many countries in Africa face similar challenges. Thus, by **regionalising their products and services for one given region, VAS companies could boost their activities in Africa and reach out to new markets**. Products could be regionalised for countries, for example, in which the agricultural activity is highly constrained by precipitations.	3

Forestry

Key specificities
➢ **The forestry domain exhibits different governance models across countries: in some parts of the world, the majority of forestry owners are from the private sector (e.g. Austria, Finland, France, Slovenia) whereas in other countries (ie. Bulgaria, Poland, Romania, Sweden), most forests are publicly managed[167].**   ➢ **Intermediate users of EO data in the forestry domain are quite heterogonous: they include several private actors (from micro-companies to larger players), public research institutions, forestry management organisations.**   ➢ **Forestry-aimed EO products are currently being used by public end users mainly (90%), rather than by private end users (10%).**   ➢ **Global initiatives, such as the UN's Programme on Reducing Emissions from Deforestation and Forest Degradation (REDD), compel participating countries to obtain highly accurate and precise data on forests and thus represent sources of opportunities for intermediate users.**   ➢ **Both Sentinel-1 and 2 data are recognised sources of valuable information along the forestry value chain.**   ➢ **The forestry value chain has historically suffered from the unsustainability of EO projects and/or applications based on EO data, due to the fact that such projects are funded by public stakeholders within limited timeframes.**

Scope/boundary

The analysis of the forestry management value chain will take into account all the components of the chain and its associated main stakeholders; the analysis will, however, exclude the analysis of the impacts of disaster managements on forests (such as storms, earthquakes, fires, etc.) which are being considered in the section dedicated to the insurance value chain.

Taxonomy and definitions

The Food and Agricultural Organisation (FAO) has established a shared definition of *forests*, based on three characteristics: land area (minimum 0.5 hectares), tree height (minimum 5 metres), and crown cover[168] (at least 10 percent). According to the United Nations Economic Commission for Europe (UNECE), the forestry sector is considered to include "the forest resource, as well as the production, trade and consumption of forest products"[169].

In addition, the FAO provides a definition of what a "tree" is: "a woody perennial with a single main stem, or, in the case of coppice, with several stems, having a more or less definite crown; includes bamboos, palms and other woody plants meeting the above criteria"[170]. Most forests have different layers:

- The *forest floor*: mostly covered with decaying leaves, twigs, fallen trees, animal waste, moss and other organic materials
- The *understorey*: made up of bushes, shrubs and young trees
- The *canopy*: a roof made of the intertwined branches, twigs and leaves of the forest's taller trees
- The *emergent layer*: which consists of the tallest trees which stick out above the canopy

Throughout the analysis of the forestry value chain, the EARSC taxonomy will be applied to the forestry value chain. In accordance with that taxonomy, the following industries will be looked at: Forest management, Forest Services, Commodities, Logging industry, Wood, Paper and pulp industry, Forest policy, Forest machinery, Forest Policy makers.

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[167] *FAO. 2007. Private forest ownership in Europe. [ONLINE] Available at: http://www.fao.org/docrep/010/a1346e/a1346e06.htm. [Accessed 8 June 2016].*
[168] *Crown cover can be defined as the forest area covered by vertically projected tree crowns*
[169] *UNECE, 2011. The European Forest Sector Outlook Study II, 2010-2030*
[170] *FAO, 2006. Forests and Climate Change Working Paper 4. Choosing a forest definition for the Clean Development Mechanism. Link: http://www.fao.org/forestry/11280-03f2112412b94f8ca5f9797c7558e9bc.pdf.*

The table below summarises the main definitions related to the forestry value chain:

Main definitions related to the forestry value chain	
Deforestation	Refers to change of land cover with depletion of tree crown cover to less than 10 percent. Changes within the forest class (e.g. from closed to open forest) which negatively affect the stand or site and, in particular, lower the production capacity, are termed forest degradation.
Forest Degradation	Takes different forms, particularly in open forest formations, deriving mainly from human activities such as over-grazing, over-exploitation (for firewood or timber), repeated fires, or due to attacks by insects, diseases, plant parasites or other natural sources such as cyclones. In most cases, degradation does not show as a decrease in the area of woody vegetation but rather as a gradual reduction of biomass, changes in species composition and soil degradation. Unsustainable logging practices can contribute to degradation if the extraction of mature trees is not accompanied with their regeneration or if the use of heavy machinery causes soil compaction or loss of productive forest area.

Value chain description

Overview of industry/domain

Today, more than half of the world's forests (by area) are found in just five countries: Russia, Brazil, the US, Canada and China[171]. Forests are multi-faceted natural resources: they are valuable sources of industrial wood and fuel, sites of rich biodiversity, prevent soil erosion, modify local climate and store carbon. Forests are not limited to these ecological functions but also have economic functions since they can be affected by the occurrence of insect infestations, forest fire, heavy snowfall or windfall events[172]. This economic dimension of forest monitoring should not be underestimated: in 2008, **the wood-based manufacturing industry in the EU was employing about 2.8 million people, generating more than EUR 400 billion turnover**[173].

The forestry sector is composed of a wide range of different actors, which can vary from one country to the other, depending on the structure of the forestry supply chain and especially the importance of public stakeholders in the sector. Indeed, according to a study performed by the FAO on 38 European countries, 49.60% of forests are privately owned while 50.10% are public (the remaining 0.3% are other ownerships, neither public or private). Some European countries are characterised by a predominance of private ownership; such as Slovenia and Austria (approximately 80% of privately owned forests for both countries), whereas other countries, such as Poland and Romania, have a majority of publicly owned forests (where more than 80% of the forests are public)[174].

Hence, four main actors can be identified: **forest owners** which can be private or public (ie. forest cooperatives, forest management groups, etc.), **forest companies** (logging companies, wood-working industries, pulp and paper producers, etc), **public authorities** (ie. local authorities, governments, international organisations, etc.) which can have a variable role depending on the structure of the forestry sector per country, and the **citizens or consumers** that benefit from the economic and environmental aspect of the forests. More globally, stakeholders which profit from forestry-related geospatial information are much more numerous: scientists working on forest management, service providers (e.g. ministries responsible for the provision of transport networks, telecommunication, water, schools, veterinary services and electricity), and non-governmental organisations (NGOs) that need data on which they can base their programmes and targeted actions[175].

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[171] University of Michigan. 2010. Global Deforestation. [ONLINE] Available at: http://www.globalchange.umich.edu/globalchange2/current/lectures/deforest/deforest.html. [Accessed 18 May 2016].

[172] Schardt, Mathias; Granica, Klaus, 2013. Improved information of forest structure and damages.

[173] Copernicus, 2013. Satellites support monitoring of Europe's green lungs. Prepared by ESA and the European Commission. September 2013.

[174] FAO. 2007. Private forest ownership in Europe. [ONLINE] Available at: http://www.fao.org/docrep/010/a1346e/a1346e06.htm. [Accessed 8 June 2016].

[175] Tuomas Häme VTT Technical Research of Finland Ltd and the Forestry TEP Team, 2014. Forestry Thematic Exploitation Platform.

As stated above, **forests have a sound economic value** throughout the exploitation and transformation of wood for example. Thus, the forest industry is composed of five main sub-sectors: wood working, furniture, paper and pulp manufacturing, and bio-refinery which all produce a range of goods which are all represented in the figure below.

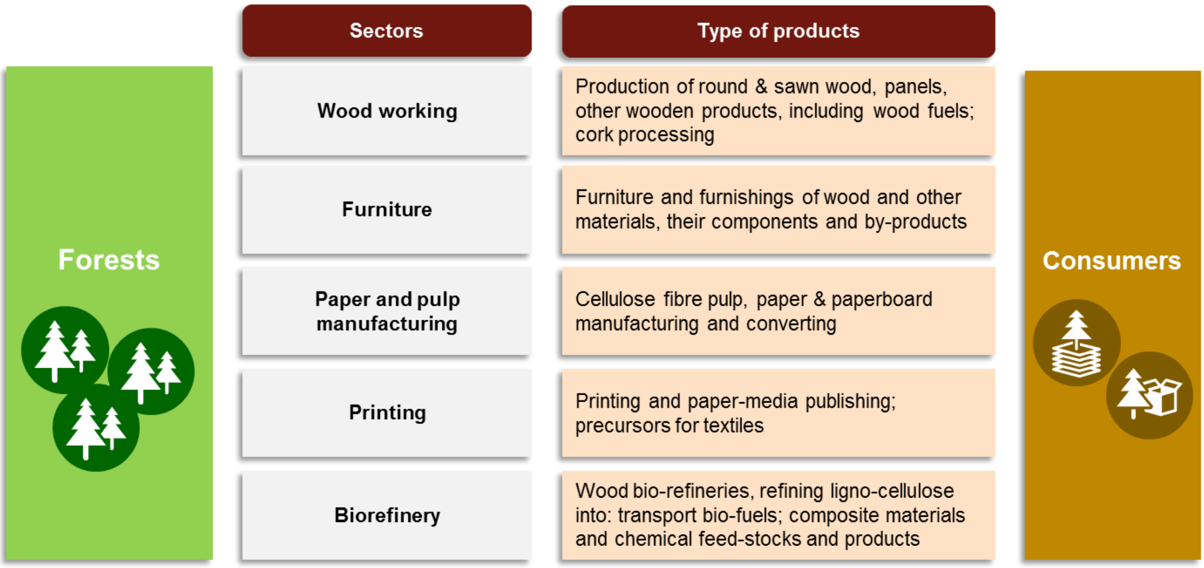

Figure 53 - Components of the forest-based industries (source: PwC-STRATEGY& analysis)

Managing forests in a sustainable way is a top political priority worldwide which has been recognised by the UN Intergovernmental Panel for Climate Change and implies balancing the different roles of forest systems accordingly. Indeed, forests are a highly important source of green carbon and in 2008, the share of bio-based in the pulp and paper sector was 54.40% of total primary energy consumption[176]. Rapid population change and economic incentives have very negative impacts on forest ecosystems, which suffer from gradual degradation as a result. Rates of deforestation are considerable – since 1990, around 129 million hectares of forest have been lost (the size of South Africa) according to the FAO[177]. The improvement of forest management systems has been set as an important issue to be tackled urgently. EO data can definitely contribute to improving the management of forests worldwide by providing accurate, reliable and complete data on forests.

One example of improvement of forest monitoring systems is **throughout the performance of National Forest Inventories (NFI)**. NFIs are performed by public authorities (local, federal, regional, etc.) in order to provide continuously updated information regarding the state, nature and evolution of a given nation's forest resources. Major efforts have been undertaken at national levels to improve the forest area covered by NFIs, in particular in the context of the UN REDD programme. Indeed, in 2010, NFIs were performed on approximately 2.4 billion of hectares of forests, which corresponds to more than half of the forested area[178]. In this context, EO data provides more precise information in a shorter period of time than what could be done by field inspections.

Forest fires have devastating impacts on the world's forests. Indeed, Russia, suffered from the highest tree cover loss in the world from 2000 to 2012, with a total of 5 million hectares of loss in 2012 alone[179]. This significant tree loss is mainly due to forest fires particularly in the Russian boreal forest, which is dominated by conifers. There are different techniques to detect forest fires. Ground stations, for example, use human surveillance whereas ground automatic detection systems make use of cameras on buildings and towers. However, both techniques are limited by the costs and limited areas covered by the detection and monitoring systems. EO data on the other hand, can

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[176] *Forest-based sector technology platform, Innovation Trends European Forest-based Sector Delivering Bio-value. [ONLINE] Available at: http://www.forestplatform.org/files/Innovation_trends_final3.pdf*

[177] *FAO. 2016. The Global Forest Resources Assessment 2015. [ONLINE] Available at: http://www.fao.org/forest-resources-assessment/en/. [Accessed 8 June 2016].*

[178] *Ronald E. McRoberts, Erkki O. Tomppo, Erik Næsset. 2010. Advances and emerging issues in national forest inventories. [ONLINE] Available at: http://www.tandfonline.com/doi/pdf/10.1080/02827581.2010.496739. [Accessed 27 May 2016].*

[179] *C. Hüttich, M. A. Stelmaszczuk-Górska, J. Eberle, P. Kotzerke, C. Schmullius. 2014. OPERATIONAL FOREST MONITORING IN SIBERIA USING MULTI-SOURCE EARTH OBSERVATION DATA. [ONLINE] Available at: http://sibjforsci.com/upload/iblock/0f6/0f6ebe1843d44f21767cd5eae77862a2.pdf. [Accessed 8 June 2016].*

provide a more affordable and efficient solution to monitor forest fires via an increased revisit time which is crucial for real-time monitoring.[180]

Illegal logging practices, which take place when timber is harvested, processed, transported, bought or sold in violation of national laws, can have **important economic, social and environmental impacts**. Illegal logging can lead to the degradation of forests, and thus impact habitats and biodiversity. In Indonesia for example, illegal logging threatens the habitats of orang-utans on the island of Borneo.[181] As an example, illegal clear-cutting in Russia is estimated to account for approximately 25% of all logging activity in this country[182].

Value chain characterization from an EO data usage standpoint

Current use of EO data

(M EUROS)	Overall EO downstream market	% of the overall market for forestry only	EO downstream revenues for forestry
2012	786	7.80%	61.38
2015	911	4%	36.44

Table 19 - EO downstream revenues in Europe for the forest industry (Sources: EARSC; PwC-Strategy& analysis)

In the forestry sector, EO data has a recognised added-value: satellite-derived information provides data and information that could not be retrieved by field information. Forestry is among the top ten sectors in terms of revenues generated within the EO market[183] and accounted, in 2015, for 4% of the overall EO downstream market. The significant revenues' cut between 2012 and 2015 can be explained by the fact that most clients of forestry related issues are actors from the public sector. Hence, this may explain the fact that the EO market for forestry related issues is considered as being unsustainable.

In order to calculate a high estimate of the revenues related to forestry applications based on EO data, the methodology chosen was to base the analysis on the value of the overall GIS market for Europe, which is significantly larger than the EO downstream market. The portion of the overall GIS market that is for forestry only is estimated as being similar to that for the EO market, and hence is given as 4%.

(M EUROS)	Overall GIS market for Europe	% of the overall market for forestry only	GIS revenues related to forestry
2015	1,352	4%	54.08

Table 20: GIS revenues in Europe for the forestry industry (Sources: Technavio; EARSC; PwC-Strategy& analysis)

EO data is used to develop services which provide a **panoptic view of forest mapping and forest change mapping** and more particularly to produce maps supporting the completion of **National Forest Inventories (NFIs)**. Indeed, EO data can improve the precision of the NFIs submitted by public authorities by providing an ever-more accurate overview of the states of the forests. Remote sensing makes it possible (and easier) to cover remote areas more precisely as well as identify boundaries between different land-use categories.

EO data is also a highly useful tool for **monitoring the illegal logging of forests**. Indeed, by using high resolution data from various satellites, forest managers are able to annually compare high-resolution maps of forests in order to monitor the evolution of forest coverage and identify illegal forest cuts. As an example, the

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[180] University of Southampton, Lund University, Univeristy of Warsaw, International Institute for Geo-information science and earth observation. 2009. Forest fire detection for near real-time monitoring using geostationary satellites. [ONLINE] Available at: https://www.itc.nl/library/papers_2009/msc/gem/manyangadze.pdf. [Accessed 8 June 2016].
[181] Illegal logging portal. 2015. Major impacts. [ONLINE] Available at: http://www.illegal-logging.info/topics/major-impacts. [Accessed 8 June 2016].
[182] C. Hüttich, M. A. Stelmaszczuk-Górska, J. Eberle, P. Kotzerke, C. Schmullius. 2014. OPERATIONAL FOREST MONITORING IN SIBERIA USING MULTI-SOURCE EARTH OBSERVATION DATA. [ONLINE] Available at: http://sibjforsci.com/upload/iblock/0f6/0f6ebe1843d44f21767cd5eae77862a2.pdf. [Accessed 8 June 2016].
[183] EARSC (2015). A survey into the State AND Health of the European EO Services Industry. Prepared by EARSC under assignment from ESA, September 2015.

French Regional Forest Directorate of Rhône Alpes (a region in France) has been able to detect over 1600 illegal cuts in French forests in 2013-2014 after starting to use EO data[184]. Indeed, the local authorities used a service provided by a French Platform in order to access EO data freely (such as data from RapidEye and Spot) which were then combined with Landsat images. The combination of images allowed the local authorities to annually compare high-resolution maps of the forest to identify the illegal forest cuts.

EO data has proven to be of incomparable use to public and non-profit organisations to **monitor forest fires**: satellite derived-information can contribute to the identification, in real-time, of forest-clearing fires and low-intensity fires, in addition to their evolution. In order to do so, service providers require satellites with a sufficient resolution to detect forest fires in real-time. Global Forest Watch, which is a programme part of the World Resources Institute, provides free real-time maps using mainly EO data, with coloured dots representing fires and their intensity everywhere throughout the world[185]. In addition, the French public authority in charge of managing public forests in France (Organisation Nationale des Forêts – ONF) has been using EO data for the past 15 years in order to monitor forest fires over the French territory.

EO data is used by public and private forest managers to perform different types of **cartographies**: of forest biophysical variables for example, which represent the volume of trees in order to further optimise forestry harvests and of the different types of vegetation, to increase the knowledge on the composition and nature of the forest. EO data can also be used to **monitor the impact of tree cuts within a forest by forest companies and public authorities which need to keep track of forest activities**, in order to optimise forest exploitation and minimise the environmental impact of such activities. Indeed, human exploitation of forests can have drastic impacts on land degradation.

EO also brings a substantial contribution to the sustainable management of forests, thanks to several initiatives led on a global scale. As an example, **Reducing Emissions from Deforestation and Forest Degradation (REDD+)** is an approach developed by the international community to mitigate the impacts of global warming on forests and their biodiversity. The logic of REDD+ is to reward governments and local communities for reducing deforestation and achieving verifiable emission reductions. In this context, countries need to benefit from a good forest monitoring system in order to provide the most relevant and precise measures related to carbon emissions coming from deforestation and degradation. EO contributes to this programme by determining land use and forest extent, by detecting, monitoring and quantifying changes, by detecting forest degradation, and by contributing to the quantification of stem volume and carbon stock changes.

The figure below summarizes the main applications of EO data along the forestry value chain:

[184] *Eurisy. 2016. The French Region Auvergne-Rhône-Alpes uses satellite information for sustainable forest management. [ONLINE] Available at: http://www.eurisy.org/good-practice-the-french-region-auvergnerh%C3%B4nealpes-uses-satellite-information-for-sustainable-forest-management_189. [Accessed 6 May 2016].*
[185] *Citylab. 2015. Mapping Indonesia's Man-Made Forest Fires in Real Time. [ONLINE] Available at: http://www.citylab.com/weather/2015/09/mapping-indonesias-man-made-forest-fires-in-real-time/407410/. [Accessed 27 May 2016].*

Type of applications	End users	Benefits
• Forest resources and change mapping	• Public authorities (local, federal, regional, etc).	• Support to perform National Forest Inventories (NFIs) • Detection of illegal logging
• Map of forest fires (Detection and monitoring of fires)	• Governmental authorities • NGOs	• Near real-time monitoring of forest fires
• Forest cartographies (tree species, biophysical variables, etc)	• Public authorities • Forest companies	• Monitor the impact of tree cuts • Optimization of forestry harvest and exploitation
• Applications developed in the context of the REDD programme	• National public authorities • International organisations	• Provides more precise and completed data in the framework of the REDD programme

Figure 54 - Summary of main EO applications in Forestry (Source: PwC-Strategy& analysis)

Market structure and trends

With 34 European companies developing value added services on forestry-related issues, the forestry sector is the fourth most important sector in terms of number of companies active in Europe[186].

Intermediate users developing value added services and information products based on EO data include SMEs, larger companies such as Airbus Geo-information, public forestry management organisations (such as the French public organisation in charge of forestry management "Organisation Nationale des Forêts"), universities or research centres (such as Icube, a laboratory attached to the University of Strasbourg).

The potential market varies a lot from one country to the other: it is **particularly significant in countries where forestry owners are private and where VAS could thus support forestry**. However, forestry management is very diverse from one country to the other, and it can be challenging for service providers to elaborate products that can be applicable in many different countries. According to a study performed by the FAO, 49.60% of forests in Europe are publicly managed, with several countries such as Austria, Finland and France having a predominance of privately-managed forests and Romania, Sweden and Poland having a majority of publicly-managed forests[187]. According to the stakeholders' analysis, it is difficult to anticipate sustainable opportunities within potential users from the private sector. In addition, with most of the forestry-related projects based on EO data being funded by public organisations, the sustainability of these projects is not guaranteed.

Several publicly funded initiatives, however, enhance the use of products based on EO data by stakeholders from the forestry community. Global Forest Watch for example, as outlined in the above section, is a programme funded by the US, the UK and Norway, which aims at making worldwide data on forestry open and available to all users globally. One additional driver that could raise awareness from the forestry community with regards to the benefit of EO data is the establishment of dedicated platforms such as ESA's Forestry Thematic Exploitation Platform which has three objectives: to make a large amount of forestry-related data available (1); to enable end users to deliver applications over the web (2) and to enable expert users to test and calibrate their applications over the web and deploy it for the benefit of the community (3).

A number of institutional programmes also integrate EO data. As an example, EO data is used in the framework of the UN REDD programme. **Many developing countries are in need of EO data related to forestry management: this is especially true in Africa**, where 26 countries are UN-REDD partners and thus are in

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[186] *EARSC (2015). A survey into the State AND Health of the European EO Services Industry. Prepared by EARSC under assignment from ESA, September 2015.*
[187] *FAO. 2007. Private forest ownership in Europe. [ONLINE] Available at: http://www.fao.org/docrep/010/a1346e/a1346e06.htm. [Accessed 8 June 2016].*

potential need of assistance to obtain reliable data in the framework of the REDD programme[188]. The demand in Latin America is considered as being relatively important: it is perceived as being the second most important demand in terms of EO data after the defence sector. Countries such as Mexico and Brazil are expected to be the largest clients in order to improve their national forest monitoring programmes.[189] However, one of the **European SMEs** we interviewed has **difficulties in operating in Latin America** and has indicated that the market is mainly dominated by stakeholders from the US (mainly universities) providing services on a non-costly basis.

Analysis of the stakeholders' responses from the consultations performed through this study suggests that **forestry related geo-information services are currently being used mostly by public end users** (approximately 90%, with the private sector constituting the remaining 10% of the user base). There is a demand coming from public organisations which are eager to integrate EO-based services to support their activities. In cases where local governments do not have the financial capability to pay for such services, such as, for example, in several countries of Africa, donors may fund specific projects in the framework of the REDD programme (such as national development institutions or international donors such as the World Bank). However, there seems to be a lack of political willingness to integrate EO data in forestry related projects on the long term – there are no dedicated operational budget lines from the donors and EO data is incorporated in projects on a case-by-case basis.

With an increase of 26% of the number of companies developing value added services on forestry related activities from 2012 to 2015, the market is growing and will most probably continue to grow in the coming years, especially considering the rising opportunities in several countries.

Key Drivers	Key Obstacles
⬀ The growing number of partner countries participating in the REDD programme will create new opportunities for service providers.	⬂ The **definition of what a forest is differs** from one country to the other, which makes it particularly difficult for service providers to develop products that are applicable on a wide scale.
⬀ Service providers have exposed their upcoming strategy to better involve the forestry community in order to better define the services provided.	⬂ An assumed lack of political willingness to include an EO component to forestry-related projects limits the opportunities for service providers.
⬀ The launch of **ESA's Forestry Thematic Exploitation Platform** should raise awareness among the potential forestry end users.	⬂ Forestry-related projects based on EO data are highly dependent of public funding (mainly international donors and development agencies), which limits their sustainability.
⬀ EO data provides a highly beneficial **alternative solution to field inspections** to perform several forestry related activities such as National Forest Inventories, which will contribute to encourage potential end users to resort to such applications.	

Table 21 - Synthesis of main key drivers and obstacles in Forestry (Source: PwC-Strategy& analysis)

Data flow along the value chain

Data collection and processing platforms

In order to develop value-added services, intermediate users use a combination of EO data and in situ data. **SPOT** data, with a 1.5 metre resolution is, for example, used in order to cover large areas (such as central Africa in the framework of a project led by Airbus geo-information and the French Development Agency in the framework of the REDD programme). The high coverage of **Landsat data combined with its 30 metre resolution** makes it useful for service providers covering large areas in order, for example, to produce global maps. Intermediate users then combine EO data with in situ data such as maps or field inspections.

[188] *UN-REDD Programme. 2016. UN-REDD Programme in Africa. [ONLINE] Available at: http://www.un-redd.org/AfricaRegionalActivities/tabid/131890/Default.aspx. [Accessed 27 May 2016].*
[189] *Euroconsult. 2015. Earth Observation Requirements & Solutions in Latin America. [ONLINE] Available at: http://www.euroconsult-ec.com/shop/earth-observation/68-earth-observation-requirements-solutions-in-latin-america-.html. [Accessed 8 June 2016].*

Copernicus data adds value to the already available EO data. Indeed, among the 9 stakeholders' interviewed, all but one have indicated currently using Sentinel-1 & 2 data. The ESA Biomass mission, to be launched in 2020, will bring significant value added to provide ever more accurate measures of above ground biomass and its change over time in order to estimate carbon emissions.

GFW provides maps and forestry-related information using derived EO for free on its website. ESA is currently launching a Thematic Exploitation Platform – the Forestry Thematic Exploitation Platform (F- TEP) that will provide data and forestry-related services for non-expert users. Since 2015, a French platform – Géosud – has been launched by IGN (Institut national de l'information géographique et forestière), a French public institution under the Ministry of Ecology, which provides data and services on forestry-related issues. The Joint Research Centre's European Forest Data Centre (EFDC) provides forestry related information throughout, for example, a catalogue containing a certain number of datasets.

Outsourced and in-house EO capabilities

Considering the availability of a number of products as well as forestry related information – for example via free platforms – service providers developing value-added services rarely need to resort to outsourcing any of their activities. Service providers are most often composed of a combination of forestry experts and EO experts.

Development of value-added software, products and applications

Thanks to the stream of data available, **service providers are starting to develop ever-more innovative products** and **provide forestry experts** with tools that directly deliver reliable measurements. The services provided by private companies can also be increasingly directed towards more integrated and larger projects in which EO data is just one single component. In some cases, service providers also offer **capacity building sessions** to non-EO expert clients, in order for them to better use the products and tools.

VAS companies develop different types of products: **maps or forest change products** in order, for example, to understand the forest monitoring system. Viridian Raven, a start-up based in Austria, develops risk assessments for bark beetles in forests. They have established an **online platform where their clients can log in** and have an overview of the changes and potential risks related to bark beetles on their clients' specific territory. GFW users on the other hand can, in addition to accessing the interactive map of the world's forest online, subscribe to **specific alert functions** such as fire alerts on a pre-defined territory. In the framework of the REDD programme, GFW also provides specific information related to the impact of deforestation on carbon emissions.

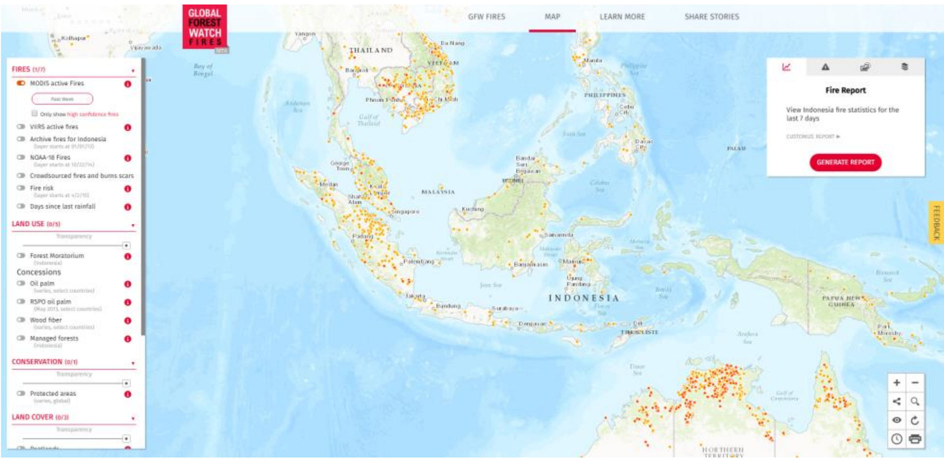

Figure 55 - Extract from the Global Forest Watch Fires map (here in Indonesia) available online on June 9th, 2016 (Source: GFW website)[190]

End users

Currently, **the majority of EO data end users are from the public sector**: large international donors (such as the World Bank), governmental authorities (such as ministries in charge of forestry-related issues), national public authorities in charge of forestry management (such as ONF), national development institutions such as the German development agency (GIZ), the French Development Agency (AFD), NGOs working on climate change or sustainable forestry issues, and research organisations.

[190] *Global Forest Watch . 2016. Global Forest Watch Fires. [ONLINE] Available at: http://fires.globalforestwatch.org/map/#activeLayers=activeFireStrategy&activeBasemap=topo&x=111&y=0&z=5. [Accessed 9 June 2016].*

Private end users of EO forestry-related issues are: forest owners, private companies, forestry cooperatives (who manage harvests) or associations who manage the forest "harvest" and need information in order to better monitor them.

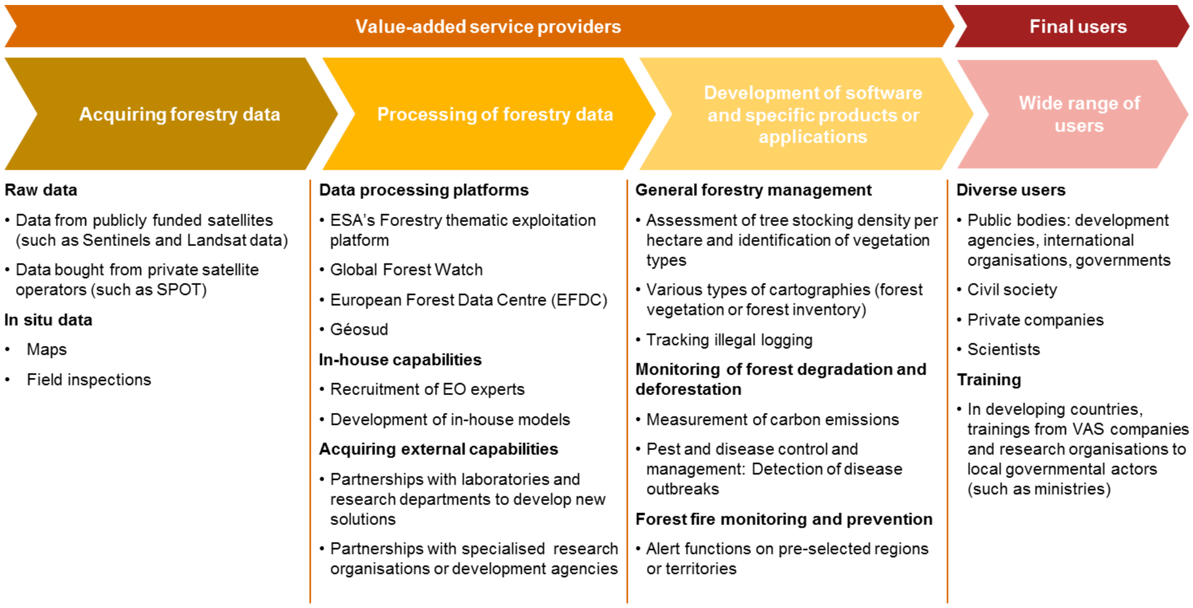

Figure 56 - Data flow along Forestry value chain (source: PwC-STRATEGY& analysis)

Current role of Copernicus

According to the consulted stakeholders, Sentinel-1 and 2 data are currently already used by many of the public and private intermediate users. **Sentinel-1 data**, thanks to its short repeat frequency, is particularly useful to monitor vast forest regions and more specifically in order to detect illegal logging and deforestation.

The combination of **Sentinel-1 and Sentinel-2** data will bring added value to global forest monitoring systems which provide a sufficient amount of comparable data in order, for example, to perform National Forest Inventories and country wide maps. **Sentinel-2 data combined with SAR data** is particularly suitable to measure forest biomass (in the framework of the REDD programme more specifically) and to monitor changes in forest cover (reductions due to deforestation or natural disasters, for example, or increase of forest areas through afforestation). Copernicus data is, however, not particularly useful for degradation assessments, which require more precise information.

ESA and EARSC case study on forest management in Sweden

In 2016, ESA and EARSC performed a case study aiming at examining the impact and more specifically the economic benefits of satellite imagery, including EO, on forest management in Sweden. Sweden was chosen because it is a country dominated by forests (they cover approximately 70% of its territory). The case study starts with the construction of a value chain representing all of the actors participating in the activity, including: the Swedish Forest Agency, other users such as other government departments, county boards, NGOs, EO/GI service providers; beneficiaries of added value services such as private forest owners, forest companies and other industries.

The case study then analyses the different cases in which satellite imagery is used in forest management in Sweden: validation of forest stands, storm damage, clear-cutting, and the Swedish Environment Protection Agency, which uses classifications of spruce, broad leaf, pine etc. According to the analysis performed, clear-cutting is considered as being the most operational of all of these uses.

Satellite imagery is considered as having a range of economic benefits: on the core value chain, the availability of satellite imagery has allowed for diametrical change in forest management. The Swedish Forest Agency is estimated to have benefited from organisational benefits which amount to around EUR 9.5million. According to the analysis performed, Private Forest Owners also benefit from the availability of satellite imagery to perform activities such as replanting and thinning. Forest companies on another hand benefit from satellite imagery in two ways: it increases the number and quality of the timber and the light legislation reduces the costs to the industry and improves competitiveness. Citizens and the local economy benefit from satellite imagery in a wide range of ways, including for example ecotourism. By combining all of the quantifiable benefits on the range of stakeholders, the total economic return is estimated to be between EUR 16 million and EUR 21.5 million per year.

The role of the Copernicus Core Services in forestry-related issues

The Copernicus Land Core Service develops several products which may be relevant for forestry related issues. Although there is no dedicated Copernicus core service related to forestry related issues, the Copernicus Core Land Service provides specific products that are being used by forestry intermediate and end users, under the pan-European component. In addition to these products, the project EUFODOS (European Forest Downstream Services – Improved Information on Forest Structure and Damages) aims at developing specific forest downstream products.

The below table describes the main products from the Copernicus core services which may be related or useful to forestry issues.

Name of the core service	Name of the product	Detail
Copernicus Land Monitoring Service- pan European component	Tree cover density 2012	This product provides maps of tree density over Europe. It has no minimum number of pixels to form a patch and a minimum mapping width of 20 m.
Copernicus Land Monitoring Service- pan European component	Forest Type 2012	The forest type product consists of two sub-products: one dominant leaf type product as well as a support layer which maps, based on the previous product, trees under agricultural use and in urban context

Table 22 - Main products from Copernicus services in Forestry (Source: land.copernicus.eu)

CASE STUDY

Mapping forests in Mexico in the framework of the REDD programme

Presentation of ESA's Forestry Thematic Exploitation Platform (TEP)

As outlined in the above section, ESA is currently launching a dedicated platform, the ESA Forestry Thematic Exploitation Platform (TEP). The elaboration of this platform has been delegated to VTT Technical Research of Finland Ltd – the leading research and technology company in the Nordic companies – which is the Prime Contractor to implement the platform. VTT focuses on a certain number of research areas with an aim to enhance the international competitiveness of companies, society and other clients. In addition, a certain number of subcontractors are responsible for the implementation of other components of the platform. CGI UK, a company providing end-to-end IT and business process services is charge of the technical implementation of the platform. The Rutherford Appleton Laboratory, operated by the British science organisation "Science and Technology Facilities Council" (STFC), which is British science, is in charge of processing systems and cloud computing. Arbonaut, A Finnish technology company, is a world leader in developing information and GIS services and is in charge of forestry services. Spacebel, a Belgian space systems and software engineering company operating in the Space and Earth monitoring applications sectors is in charge of the assessment of the sustainability of the platform and planning.

This dedicated platform will be a one-stop shop for forestry remote sensing services for both the academic and commercial sectors and will provide services based on pre-processed Copernicus and other types of satellite data, ancillary data, and computing power. The platform will also provide access to commercial software and services.

The Forestry TEP provides the following functionality to its users:

- Access to relevant EO data
- Efficient remote exploitation
- Various EO and GIS toolboxes
- Support of in-situ data
- Simple user interface and procedures for range of services
- Advanced features for more complex tasks
- Virtual environment for expert users
- Product accuracy assessment
- Visual data and product analysis
- Effective data management
- Various EO and GIS toolboxes
- Service development and publishing
- Sharing/licensing products & services
- Accounting support
- Collaborative working
- Community features, forum
- Support helpdesk

Service	Source Data
Basic mapping of tropical forest cover	Sentinel-1 (satellite SAR)
Basic mapping of forest cover	Sentinel-2 (satellite optical)
Mapping bi-temporal forest cover change	Sentinel-2 (satellite optical)

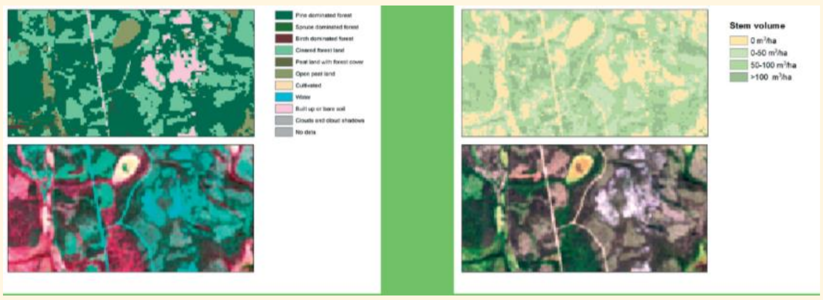

Figure 57 - Examples of maps available on the Forestry TEP *(Source: TEP Brochure available on Forestry TEP http://forestry-tep.eo.esa.int/)*

This platform will serve various user-groups which include: Copernicus core services, UNREDD and other international programmes such as GFOI, National forest inventories, universities and research centres, forest managers, value adding industry, NGOs, etc.

In order to define the different types of needs that were going to be addressed by the platform at best, VTT has been collecting inputs of stakeholders from the forestry community, who have an extensive experience (from 10 to 20 years) in the sector as well as current users with new ideas such as Finnish forest owners. In addition to this, they have been in contact with 40 to 50 user organisations in order to understand how a product can respond to a user need.

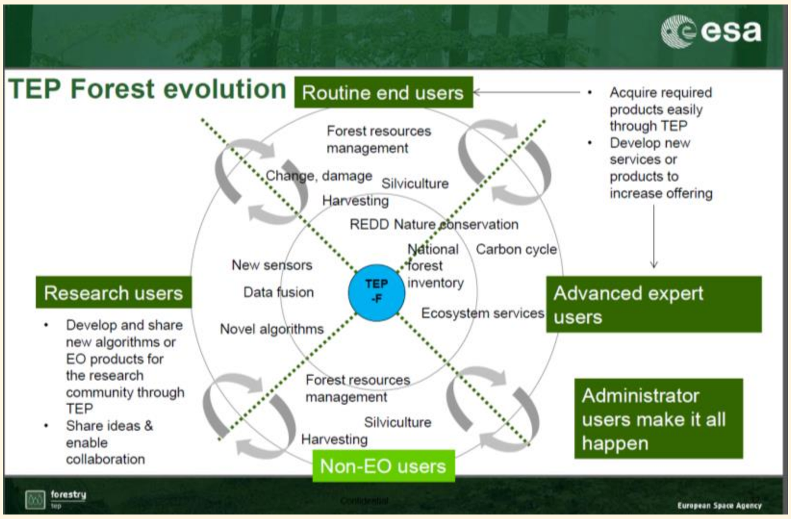

Figure 58 - Overview of TEP Forest evolution process
(Source: VTT Technical Research of Finland Ltd and the Forestry TEP Team ESA)

Pilot project: monitoring of forest carbon in Mexico

In this context, both ESA and the project stakeholders have decided to launch two pilot projects in order to showcase the added-value and benefit of the Forestry TEP to fulfil forestry requirements, to provide a means for close engagement with a key subset of users, and to deliver a service of value to many users.

One of these pilot projects has been launched in March 2015 in Mexico in the **temperate and tropical regions of Chiapas** (73,311 km^2) **and Durango** (123,317 km^2) **and is currently in its initial development phase**. Indeed, several Mexican stakeholders have been developing resources and competences to better use and benefit from EO data in the forestry sector. The objective of this project is to **use Sentinel-1 and 2 data in order to map forest cover** in the framework of the REDD+ programme.

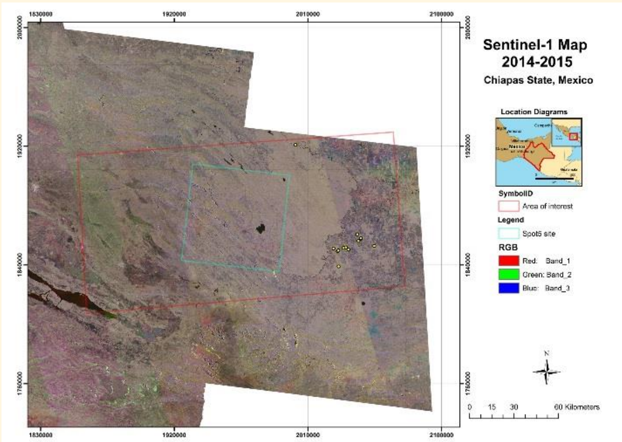

Figure 59 - Example of end users training session in Mexico (Source: TEP Brochure – available on the Forestry TEP http://forestry-tep.eo.esa.int/)

Two main end users will be involved in this project. Firstly, the **Ministry of Environment and Natural History of the state government of Chiapas**, a key cooperation partner in the earlier FP7 project ReCover aiming at better exploiting and using EO data in the framework of the REDD programme. The second stakeholder is in the region of Durango, the main state for commercial forestry in Mexico. The **University of Durango** is currently working on specific methods aiming at improving forest management and REDD. The team members of the University involved in these research activities have been collecting field plot data in the ESA project EducEO throughout a specific mobile application. EducEO is an ESA Scientific Exploitation of Operational Mission which aims at fostering the use of new and emerging information and communication technologies (ICT) such as location-enabled mobile devices.[191] The team also supports another VTT-

[191] *Educao. 2016. Aims & Goals. [ONLINE] Available at: https://educeo.net/. [Accessed 10 June 2016].*

coordinated ESA project AccuCarbon in which a novel approach is developed for the monitoring of forest carbon by combining change detection and forest growth models. The AccuCarbon methodology will be applied in the F-TEP demonstration.

The objective is to **involve the user in the production of these images as much as possible**. Hence, the project stakeholders, and in particular VTT, will communicate as much as possible and provide relative training in order for them to use and interact with the F-TEP platform.

Figure 60 - Sentinel-1 Map 2014-2015 of Chiapas Region in Mexico (Source: VTT Technical Research of Finland Ltd and the Forestry TEP Team ESA)

Training data and data for the accuracy assessment for the pilot project will be collected from randomly sampled Pleiades data locations in the Chiapas and Durango states. Within each Pleiades image a systematic grid of sample plots is defined. The forest proportion of each plot will be evaluated visually within each Pleiades image. In total, 100 plots (one plot being 40 meters by 40 meters) will be evaluated from each image. Out of these 100 plots, 25 will be used for model training whereas 75 for an independent accuracy assessment. The results between both states may be different because Durango is characterised by more dense and concentrated forest areas whereas in Chiapas the land use pattern is very scattered.

The **integration of Sentinel-1 and 2 data will be gradual** and is planned as follows. All available Sentinel-1 images have already been acquired. The images will then be calibrated using the toolboxes of the Sentinel Application Platform (SNAP) or VTT in-house software in case the appropriate tools are not available. A mosaic image will then be constituted using VTT in-house software. The forest map should be computed by applying a random forest classifier of the Orfeo toolbox, which is an open source library for remote sensing images funded by the French Space Agency (CNES). This specific map follows the Mexican definition of a forest which has to respond to several criteria: a minimum area of land of 1.0 ha, an average height greater than 4 meters, and a canopy cover greater than 10%. The Sentinel-based forest maps will be published in GeoTiff format with a 40m pixel size. Sentinel- 2 data images will be selected and used if they are relatively cloud-free. In addition, lower resolution data from Sentinel-3 for example may be used in order to improve the calibration.

Copernicus prospective enabled revenues

Since all the stakeholders involved in this project are from the public sector, the majority of the projected impacts are qualitative. The quantitative impacts will be visible on a longer term since the platform should enable REDD- partner countries to acquire more precise and accurate information regarding carbon emissions linked to in the framework of the REDD programme. Indeed, considering that the public authorities using the platform are able to give precise accounts of a reduction of their carbon emissions, they will purchase specific payments based on the observed emissions and the projected emissions. This economic impact is however to be counteracted by the fact that most of the actors responsible for deforestation are commercial (in order to harvest cocoa, oil palm, rubber and soy) and the ability of REDD payments to provide incentives to limit deforestation can be considered as quite limited.

Provided that data access is ensured and smooth, the objective of the F-TEP prime project stakeholder is that **Sentinel-2 data accounts for up to 90% of the entire data processed** in order for the end users to benefit from the quality and resolution of the images. On the other hand, if data access is not ensured and challenging, which may be the case with regards to the current lack of reliable infrastructure, Sentinel-2 data would account for only 10% of the entire data.

The integration of Sentinel-2 data in the Chiapas and Durango regions in Mexico **will improve significantly the quality of the forest mappings**, **with regards to the identification of tree species for example**. Indeed, the spectral bands of Sentinel-2 mission are particularly suitable to assess important vegetation structural and biochemical variables.

The elaboration of forest maps using Sentinel-1 and 2 data should greatly facilitate and improve the efficiency of the Ministry of Environment and Natural History of the state government of Chiapas – indeed, **EO data replaces field inspections which were very time consuming at the time.** Obtaining frequent, precise and reliable information on Mexican forest resources is a significant challenge in Mexico.

The establishment of the Forestry TEP is also expected to generate sound impacts for the forestry end users: it should firstly encourage a rising number of forestry stakeholders to use products based on EO data. In addition, the platform should boost the heterogeneity within the platform's users: the proportion of non-expert and intermediate users should rise in comparison with the number of expert users. VTT expects that the proportion of "type" of user should be relatively equal. The platform is a unique and innovative tool which makes it possible to **continuously update forest resources** which will enable end users to obtain the appropriate information they are looking for. In addition, in the framework of the implementation of the F-TEP, approximately one yearly dedicated event will be organised and assemble the forestry community in Mexico. Today, the national stakeholders for forestry-related issues within the Mexican community rarely have the opportunity to network with one another and exchange experiences. The internal national network will hence be reinforced and enlarged which should contribute to driving interest towards products based on EO data in the forestry-related domain.

Copernicus socio-economic impact assessment

In order to perform the assessment of the socio-economic impacts of the Copernicus programme in the forestry value chain, 9 major European sectoral stakeholders were interviewed: 5 of which are private companies (including one start-up, one large player and 3 small or intermediate companies), two research centres, one international organisation and one public forest organisation.

Copernicus current enabled revenues

90% of the stakeholders interviewed within this assessment are currently using Copernicus data with a view to developing forestry-related products and applications to a certain extent - **Copernicus data currently contributes to approximately 11.50% of the total amount of EO data used (minimal estimation)**.

Using EASRC figures as a proxy, the EO downstream revenue for the forestry domain is approximately EUR 36.50 million. With approximately 11.5% of all EO data used being Copernicus data, **a conservative estimate of the value of Copernicus data to forestry management is just under EUR 4.20 million in 2015**.

This should be treated as a very conservative estimate of the value of Copernicus data for two primary reasons. The first is the implicit assumption within these calculations that the value of Copernicus data and the value of non-Copernicus EO data is equivalent to the ratio of their data usage. However, it is likely that the value of Copernicus data is higher than the value of non-Copernicus EO data, given the additional benefits that Copernicus data provides. For example, Copernicus data offer advantages such as higher frequency visit and non-optical data, which, as explained above, are useful within the forestry management domain. As a result, the share of EO downstream revenues is likely to be higher.

A second reason why the actual contribution of Copernicus data may be higher is because at present the **calculation only captures the revenue obtained by EO downstream companies** (the intermediate users). The contribution of Copernicus data to the end users, of whom 90% are from public sector, may be sizeable, but it is difficult to determine an estimate of the size based on the available information and data. Based on available Eurostat data, in 2013, total output for forestry and logging services across EU countries who report data in this category is almost EUR 4 billion. A proportion of forestry and logging services consists of forest inventory services and forest management consulting services, which may align with some components of the forestry management value chain. A proportion of those services' revenues can be attributed to Copernicus data. However, the exact size is difficult to determine, and thus it has been omitted from present calculations to ensure the rigour of the calculations.

Even if such data were available, this output value does not include public services in the same domain, and therefore still omits parts of the forestry management value chain.

Non-monetary benefits of Copernicus

Regarding the general forestry sector, the added value of Copernicus data is currently less significant. Sentinel data contributes to applications and projects aimed at **performing national forest inventories, generating country wide maps and detecting major changes** (in particular in order to prevent diseases). Globally, thanks to

Copernicus data, it will also be possible to **monitor illegal logging systematically**. Copernicus data is however not useful for degradation assessments – the resolution of the Sentinel missions does not reach the required preciseness.

In terms of social impacts, the availability of free Copernicus data has led to an increase of knowledge and competence in-house of service providers: as an example, the French institution in charge of forest management (ONF) has been developing specific EO expertise within its R&D and Innovation unit in order to explore the potential added value of EO data in the institution's activities.

The integration of Sentinel data in forestry related projects contributes to reducing the **negative environmental impacts related to several forestry activities**: through an improvement of the monitoring of deforestation and forest degradation globally, for example, or throughout a better prevention of forest fires. Indeed, by improving the prevention and monitoring of forest fires, the use of Sentinel data contributes to reducing the negative impacts on public health that can arise from such issues.

Copernicus projected contribution to the global and European socio-economic impacts

(M EUROS)	EO downstream market for forestry	Copernicus downstream revenues for forestry
2015	36.50	4.20
2020	41.10	7.60

Table 23 - Copernicus current and projected revenues for forestry (Source: PwC - Strategy& analysis)

The impact of the Copernicus programme for forestry-related services is expected to grow in the next 5 to 10 years. Using the assumption that the average CAGR in EO imagery over 2015-2020 is 12.63%, a conservative estimate of **the value of Copernicus data in 2020 is around EUR 7.6 million.**

In order to provide a high estimate of the total revenues directly attributable to Copernicus in the forestry sector, the analysis was performed on the basis of the GIS market. For methodological purposes, the shares attributable to the EO downstream market were considered as being similar for the GIS market. In 2015, the revenues directly attributable to Copernicus on the GIS market are of approximately EUR 6.21 million, significantly above the attributable revenues for the EO downstream market. In order to obtain a high estimate for 2020, since EARSC does not provide the evolution of the portion of the applications related to forestry against the total amount of applications, the methodology chosen was to take into account the fact that the European GIS market for 2015 corresponded to 2.08 times the EO market for 2015. Hence the GIS revenues for forestry applications is estimated to be of EUR 85.48 Million in 2020, with Copernicus downstream revenues to be of **EUR 15.81 Million**, corresponding to more than double of the minimal estimation.

(M EUROS)	Overall GIS market for forestry	% of Copernicus enabled revenues	Copernicus downstream revenues for forestry (high estimation)
2015	54.08	11.50%	6.21
2020	85.48	18.5%	15.81

Table 24 - Comparison of the current and prospective enabled revenues directly attributable to Copernicus for forestry management (Source: Technavio, PwC - Strategy& analysis)

Copernicus is expected to have a significant impact in terms of knowledge creation in the forestry sector and thus boost the use of EO by non-expert users. The **launch of specialised platforms is expected to contribute significantly to raising awareness of end users on the benefit of EO data to their activities**. More specifically, ESA's Forestry Thematic Exploitation Platform, which should be operational during the last quarter of 2016, will provide end users with a large amount of accessible and understandable data and services. In addition, a lot is expected from the Platform for the Exploitation of Sentinel products (PEPS): a facilitated access to pre-processed data, relatively simple biophysical products and robust and elaborated cartography products.

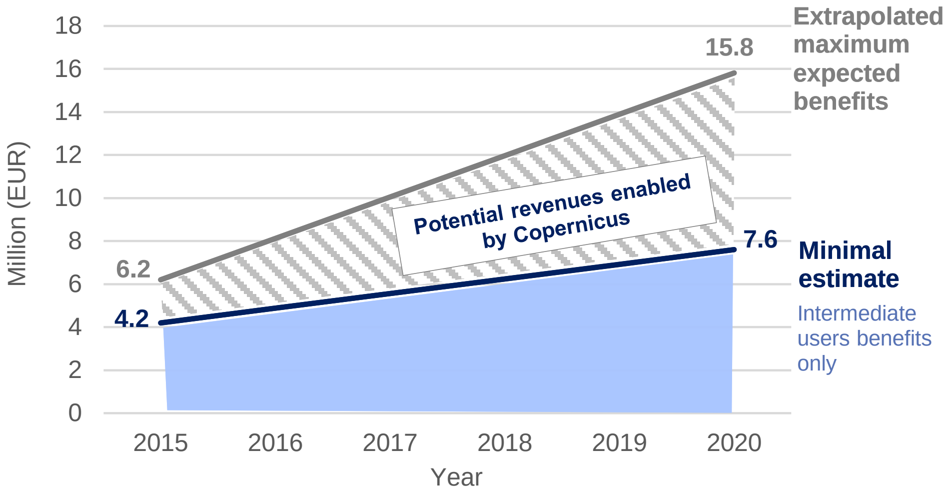

Table 25: Current and prospective enabled revenues by the availability of Copernicus data in Europe for forestry (Source: PwC-Strategy& analysis)

Over the period 2015 – 2020, Copernicus-enabled revenues in the forestry value chain are forecasted to support a cumulated total estimated at **between 270 and 510 person years** within the EO and GIS downstream markets across Europe.

It is assumed that productivity among the intermediate users was the same as for the industries NACE 62.01 and 62.02. The enabled employment estimation method used employment, turnover and GVA data from the Eurostat Structural Business Statistics. The 2020 estimates were based on E3ME growth projections for these variables.

Table 26 - Synthesis of Copernicus socio-economic impacts - Forestry (Source: PwC-STRATEGY& analysis)

Economic	• **Sentinel data accounts for 11.50% of the total amount of EO data used (minimal estimation)** • **The integration of Sentinel data in forestry-related issues should boost the use of EO by non-expert forestry users especially throughout the launch of dedicated platforms such as ESA's F-TEP (expected)**
Social	• The availability of Copernicus data increases knowledge and competence of forestry end users throughout the implementation of user friendly and specialised platforms • By **better preventing and monitoring forest fires**, the use of Sentinel data contributes to **reducing the negative impacts on public health** that are caused by such issues (Indonesia's fires for example could account for up to 3 percent of the world's greenhouse gas emissions[192]).
Environmental	• By contributing to the REDD programme, Sentinel data will **reduce the negative environmental impacts caused by deforestation and forest degradation**. Deforestation has particular negative impacts on land quality.

[192] *Brian Kahn. 2015. Indonesia's Fires Are Driving Climate, Public Health Crises. [ONLINE] Available at: http://www.climatecentral.org/news/indonesias-fires-climate-public-health-19601. [Accessed 30 May 2016].*

Voice of Copernicus users[193]: SWOT

STRENGHTS

- Regarding forestry-related issues, the Sentinel missions are of significant added-value because of the wide range of scales and the numerous thematic requirements they encompass.
- Copernicus provides data on all the forestry thematic requirements which enables the VAS companies to benefit from all the required information they need to produce their maps.

OPPORTUNITIES

- Initiatives led by international programmes and organisations (such as GFOI) are expected to boost cooperation and raise awareness within national governments.
- The rising need from many countries to systemize, standardize and improve their forest monitoring systems creates additional opportunities for service providers.
- The Copernicus programme facilitates access to forestry data throughout the world, even in certain developing countries where several areas were protected by national governments.
- The major emphasis put on the REDD initiative increases the number of countries in need of precise, comparable and reliable data and thus creates opportunities for service providers.

WEAKNESSES

- The added-value of the Copernicus land service is yet very limited for forestry-related issues since it focuses on very specific needs of users from the public sector.
- In most national or international forestry management organisations, there are yet no dedicated budget lines for the incorporation of EO products.
- One issue that has not been overcome with EO data is the importance of cloud coverage in certain regions and thus the difficulty to obtain clear and accurate images over forests in such cases.
- Training is a significant issue especially in the framework of the REDD programme: many developing countries lack the expertise and resources to process and use the data.

THREATS

- The current market for products and applications developed by VAS companies is based mainly on public funds which makes it unsustainable.
- National governments responsible for forestry management are generally not sufficiently aware of the potential added-value of EO data on their activities. This issue is particularly pressing on the African continent.
- Forest owners, which are end users who could benefit drastically from EO-related products, are yet not sufficiently aware of their potential.
- The definition of what is a forest varies from one country to the other: thus, it may be challenging for service providers to deliver a product that is useful to a wide range of different users in many different countries.

[193] PwC-STRATEGY& analysis, on the basis of interviews conducted in 2016 (cf detailed list of interviewees in the appendices)

Policy recommendations to foster Forestry management through Copernicus

Strategic pillar	***Sectoral recommendation for policy action***	***Priority level***
Pillar I: ***Ensure access to data***	***#FOR-1 - Define an adapted strategy to increase access to data*** Data access is considered as one of the main weaknesses of the Copernicus programme. Thus, the EU needs to define a specific strategy and invest in the downstream market in order to make the data available to all potential users.	1
Pillar II: ***Support innovation***	***#FOR-2 - Boost the creation of a sustainable market for EO forestry-related products*** The downstream market for forestry-related products and applications relies mostly on public funding and is thus not sufficiently sustainable. Hence, the relevant DGs of the **EC should contribute to creating a sustainable market for EO forestry-related issues** and, in this context, could develop a **coherent funding strategy of EO-related projects** (in Europe but also in Africa).	2
Pillar III: ***Increase awareness***	***#FOR-3 – Foster the promotion of the added value of EO data in forestry-related issues*** The EC should continue to encourage strongly the **launch of public campaigns throughout the world in order to showcase the added value of EO data in forestry-related issues** and ensure that an appropriate follow-up is done. This would increase the range and number of private and public end users, in the framework of the REDD programme and others, and create further opportunities for service providers.	1

Specific recommendations linked to the **REDD programme in developing countries**

Pillar I: ***Ensure access to data***	***#FOR-4 - Improve the coverage of the Sentinel-1 mission over Africa to better monitor deforestation and forest degradation*** **The added value of EO data for monitoring deforestation and forest degradation in developing countries is considerable. In the Congo basin for example, countries are in great need of improving their existing forest monitoring systems. However, they experience a lack of relevant and precise data on their regions. Thus, if the coverage of Sentinel missions (especially Sentinel 1) over Africa were to be increased and improved, the added-value of the Copernicus programme would be boosted.**	2
Pillar III: ***Increase awareness***	***#FOR-5 - Increase capacity building programmes to better monitor deforestation and carbon emissions*** Many developing countries are currently actively participating in the REDD programme. In this framework, many are benefiting from value-added services based on EO-derived information in order to better monitor the impact of deforestation and carbon emissions. Thus, **in order for these programmes to be sustainable on the long-term, it is necessary for capacity building and training initiatives to be enhanced and widened in order for local authorities to gain the knowledge and competence to access, use and process EO data.**	2

Urban monitoring

Key domain characteristics and specificities
➢ **EO data is already used for many urban monitoring products such as urban growth monitoring, land use, change detection, environmental impact management or transportation routes tracing.** ➢ **The intermediate users are VAS companies, being mainly SMEs.** ➢ **The end users are, for the great majority, local authorities which, despite some cultural barriers to use EO products and some budget reduction issues, are increasingly numerous in buying such products.** ➢ **Some private companies such as those operating in the construction industry or chain stores undergoing expansion are increasingly buying EO-based applications.** ➢ **The EO downstream market in the field of urban monitoring market is already well developed, representing EUR 45.50 million or revenues in 2015, with a growth of 480% compared with 2012.** ➢ **Copernicus has a real value added in urban monitoring, in particular Sentinel-1, as it provides a globally better product than its competitors' comparable free data. Sentinel-2 and the Copernicus Land Monitoring Service are also well adopted by the intermediate users. Copernicus' conservative estimate of the downstream market in the field of urban monitoring is of EUR 5.69 million in 2015.**

Scope/boundary

Urban monitoring is a discipline/domain that encompasses a wide range of activities aimed at planning and management of citizens' logistics, infrastructures and transportation in cities. This chapter focuses on **urban monitoring activities leveraging geospatial information.** In particular, the following areas will be analysed: land administration, urban sprawl monitoring, urban heat islands (UHI), **which means that a metropolitan area is significantly warmer than the surrounding areas due to human activities,** monitoring and management, vegetation areas monitoring, mapping and transport planning. The urban monitoring value chain includes activities that also fall into other value chains covered in this study, such as air quality, renewable energies and natural disasters: these overlapping activities are not considered here as they are already covered elsewhere.

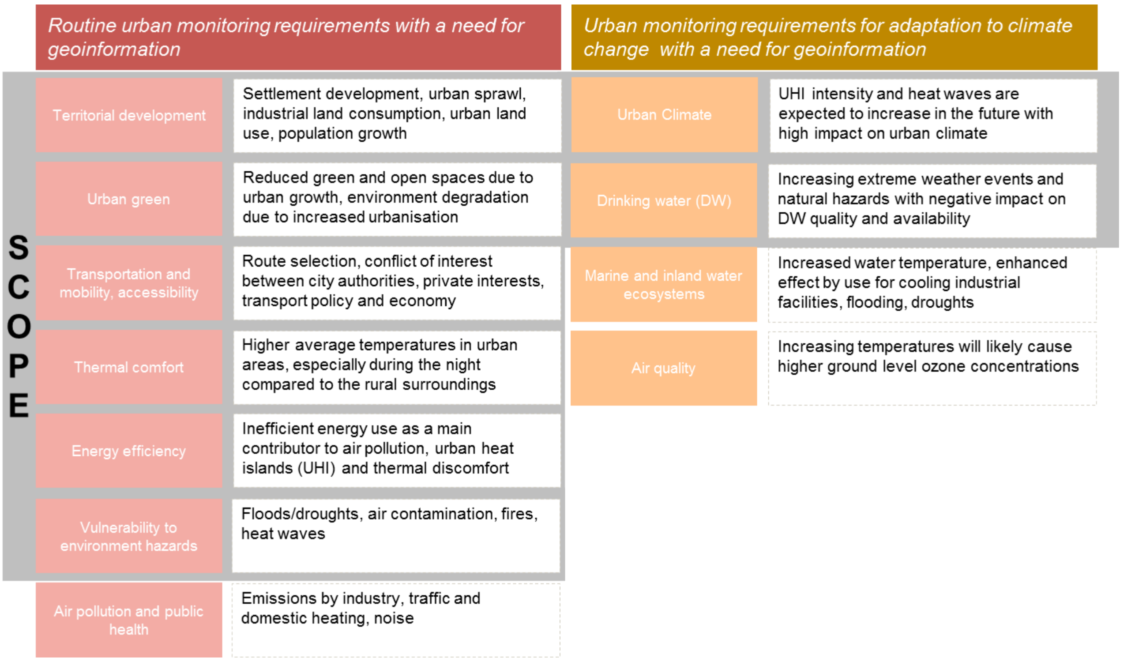

Figure 61 - Urban monitoring activities based on geo-information and scope of this chapter (source: International Journal of Geo-information)[194]

[194] *Chysoulakis, N., Feigenwinter, C., Triantakonstantis, D., Penyevskiy, I., Tal, A., Parlow, E., Fleishman, G., Düzgün, S., Esch, T., Marconcini, M., 2014. A Conceptual List of Indicators for Urban Planning and Management Based on Earth Observation.* ISPRS International Journal of Geo-information, *ISSN 2220-9964, 980-1002.*

Taxonomy and definitions

Main definitions related to the agricultural value chain	
Urban area	An urban area is a place "characterised by a built-up environment, consisting of non-vegetative, human-constructed elements (e.g. roads, buildings, runways, and industrial facilities".[195] Urban management is a set of instruments, activities, tasks and functions that ensure that the urban area can function.[196]
City planning or urban planning	City planning refers to the activities necessary to anticipate the future use of the space in a city, taking into account many factors such as the economy, the environment, culture, transportation etc. Part of their work is to subdivide a town into zones, which are managed as an entity (for example, a residential area, a shopping area etc.).
Land use	The arrangements, activities and inputs people undertake in a certain land cover type to produce, change or maintain it.[197]

Value chain description

Overview of industry/domain

54% of the world's population lived in urban areas in 2014, a percentage that is expected to rise to 66% in 2050[198]. As cities grow and expand, their management, governance and the provision of services become increasingly complex. In fact, heavy urbanisation tends to accentuate inadequate housing, poor quality urban services, spiralling land prices and construction costs, traffic congestion, and the proliferation of slums[199]. Today, **cities consume 75% of the world's natural resources, 80% of the global energy supply, and are responsible for about 75% of the global CO_2 emissions**[200].

Regulations, especially in Europe[201], compel cities to have strong urban planning strategies, to be energy-efficient and to monitor their impact on the environment and the quality of life of their citizens. These evolutionary needs raise a lot of planning and management issues, which are demographic, environmental, or structural in nature, and require a related adaptation of several key urban infrastructures.

Urban planning is closely related to the construction market, its health and the way it evolves. For the first time since the financial crisis**, in 2014, the construction industry turnover in Europe grew again by 2.90%.** With the exception of some South European countries, the construction industry serves as a growth engine, and it represented 12.73 million jobs in the EU-28 in 2012 and most revenues come from SMEs[202]. The volume of construction output should grow by 85% to $15.50 trillion by 2030, with China, US and India leading the way and accounting for 57% of all global construction growth[203].

Smart cities, where the traditional networks and services are made more efficient with the use of digital and telecommunication technologies for the benefit of its inhabitants and businesses, can become a key part of the solution to the major societal challenges to come. Smart urban monitoring contributes to the creation of cities which are optimised in terms of healthy human dwelling, coherent city planning, improved public transportation, etc.

[195] *Weng, Q, 2014. Global Urban Monitoring and Assessment through Earth Observation. 1st ed. Florida: CRC Press.*
[196] *Noort, M., 2013. Earth Observation for Urban Management, Land Adminsitration, & Spatial Data Infrastructures. Prepared by the European Commission and EO Power.*
[197] *FAO, 1999. Land Use, what is land use. Link: http://www.fao.org/nr/land/use/en/*
[198] *Department of Economic and Social Affairs, Population Division, United Nations, 2014.* World Urbanization Prospect: The 2014 Revision, Highlights
[199] *Chakrabarty, B. K., 2001. Urban Management: Concepts, Principles, Techniques and Education..* Cities, *18, n°5, 331-345.*
[200] *JRC, 2015. Science for environmental sustainability, JRC thematic report*
[201] *EEA, 2016. Urban sprawl in Europe: the ignored challenge*
[202] *Building Radar. 2014. Data for the construction industry in Europe. [ONLINE] Available at: https://buildingradar.com. [Accessed 16 May 2016].*
[203] *Global Construction Perspectives, Oxford Economics, 2015. Global Construction 2030: a global forecast for the construction industry to 2030.*

Figure 62 - Urban monitoring areas (source: PwC-STRATEGY& analysis)

Value chain characterization from an EO data usage standpoint

Current use of EO data

It is with the launch of Landsat-4 in 1984 and SPOT-1 in 1986 that for the first time the resolution of satellite multispectral images was high enough (respectively 30m and 20m) to enable the use of the remote sensing for urban monitoring applications[204]. Today, EO can play a valuable role in urban management and planning, in the areas that require geospatial information (which are presented in the following figure), as it **provides data for a number of relevant urban indicators** such as socio-economic indicators (e.g. build-up density, access to public services and networks), climate indicators (e.g. surface temperature, carbon footprint analysis) or geographic indicators (e.g. mappings, city infrastructure modelling). Although conventional data, such as survey results or energy consumption, are useful for calculating urban indicators, they are frequently inadequate due to unavailability or outdating[205], preventing successful sustainable smart city development. **EO data collection methods are easier** and often more cost-effective than in situ data collection, they **enable inter-country comparisons** and also **enhance transparency**. Another feature of EO data is its capacity for **routine periodic and unobtrusive updating**[206]. Smart cities applications rely heavily on new technologies, as those improve accessibility, offering the latest features, and often reduce costs. Hence remote sensing can be considered as common and **major driver of smart cities initiatives**. It is also the only way to get a top-down data collection approach, providing a **new type of information on the cities**.[207] Open-source data is reported to be an advantage as it provides more flexibility, enabling the users to **produce customised information**.

EO provides **measurements of physical properties** such as vegetation cover, and the impact of urban structure on micro climate and identification of UHI effect. EO is also useful for estimating accurately **population size by combining statistical data on the population and map and size of buildings, and for studying the quality of life in an area by measuring for example the temperature, the growth dynamics etc. By providing an overview of different types of information**, EO can help identify interconnections between variables and help the decision makers to implement the right projects.

A well-known EO application is to facilitate **land use and land cover classification**, such data is used by planners for land administration issues such as site selection, resource allocation, urban growth management, slum

[204] *Barnsley, M.J., Stuart B. L., 2000. Monitoring Urban Land Use by Earth Observation. Surveys in Geophysics, Volume 21, Issue 2, pp269-289.*

[205] *Chysoulakis, N., Feigenwinter, C., Triantakonstantis, D., Penyevskiy, I., Tal, A., Parlow, E., Fleishman, G., Düzgün, S., Esch, T., Marconcini, M., 2014. A Conceptual List of Indicators for Urban Planning and Management Based on Earth Observation.* ISPRS International Journal of Geo-information, *ISSN 2220-9964, 980-1002.*

[206] *Musakwa, W., Van Niekerk, A., 2014. Earth observation for sustainable urban planning. Trends and future directions. International Journal of Planning Litterature.*

[207] *Garzon, A., Palacios, M., Pecci, J., Khan, Z., Ludlow, D., 2014. Using Space-based Downstream Services for urban Management in Smart Cities.* International Conference on Utility and Cloud Computing (UCC) IEEE/ACM, *7th, 818-823.*

mapping or zoning regulation. EO is cost and time effective for **analysing urban build-up areas** as it allows rapid mapping and detection of change as well as high-speed cadastral surveying. It informs on the number, size, location, density, layout, height and volume of buildings to both private and public actors.

Extraction of EO high temporal resolution makes it a key tool to monitor the various issues related to **urban sprawl** such as unequal access to public service, optimisation of networks (e.g. transport, electricity), increase of cost related to infrastructures, connectivity with neighbouring areas[208] or consumption of natural ecosystems by urban uses.

However, EO can provide only limited information on **transportation** such as traffic counts as it requires a very high temporal resolution, but radar EO data can still provide information on traffic volumes, motor vehicle classifications and queue sizes. EO data-based mappings are also used to choose the best route for a road or a metro line[209].

All these applications can be categorised in five categories as illustrated in the following figure: Risk management, environmental and health impact management, Social impact management, City planning, Market research.

Type of applications	End users	Benefits
• **Risk management:** (Impervious surfaces Structure stability issues)	• Local authorities • Construction industry players • Research centres	• Prevention of crisis
• **Environmental and health impact management:** (Urban Heat Islands(UHI) Vegetation cover)	• Local authorities • Research centres	• Detection, prevention and mitigation of UHI • Citizen's welfare • Carbon sequestration
• **Socio-economic impact management:** (Access to public services and networks Population density)	• Local authorities • Research centres • Private actors for commercial purpose	• Fighting against exclusion and poverty • Provide the right public services at the right place • Understand the dynamics of a town (population growth, hot spots, etc.)
• **City planning:** (Mappings Routes for transport Urban sprawl management)	• Local authoritiies • Transport operators • Research centres	• Create scenarios to optimise infrastructures constructions • Identification, prevention and mitigation of uncontroled urban sprawl • Optimise a transport route and limit its negative environmental and social impacts and structure stability risks
• **Market research:** (Detection and analysis of construction sites Identification of sites for new stores)	• Private actors related to the construction industry • Major chain stores	• Advantage over competitor • Time and costs savings on market research

Figure 63 - Summary of main EO applications in Urban monitoring (Source: PwC-Strategy& analysis)

Market structure and trends

(M EUROS)	Overall EO downstream market	% of the overall market for urban monitoring only	EO downstream revenues for urban monitoring
2012	786	1%	7.86
2015	911	5%	45.5

Table 27 - EO downstream revenues in Europe for the urban monitoring industry (Sources: EARSC; PwC-Strategy& analysis)

Based on EARSC 2015 and 2012 surveys, the global EO market represents EUR 786 million in 2012 and EUR 911 million in 2015, of which respectively 1% and 5% are related to urban monitoring activities. This leads us to say that **the market for urban management is estimated to have been worth EUR 45.50 million in 2015, being almost 5 times its estimated size of EUR 7.86 million in 2012.** This considerable market growth rate can be explained by the fact that the global smart cities market is growing, it is estimated to be have been worth USD

[208] Noort, M., 2013. Earth Observation for Urban Management, Land Administration, & Spatial Data Infrastructures. Prepared by the European Commission and EO Power.
[209] Musakwa, W., Van Niekerk, A., 2014. Earth observation for sustainable urban planning. Trends and future directions. International Journal of Planning Litterature.

312.03 billion (EUR 281 billion) in 2015 and should grow by 19.40% by 2020[210], but also because new smart cities EO-based applications are being developed, such as 3D mappings, for example.

The EO market for urban management is fragmented as there are numerous VAS companies providing often quite specific services answering many different needs as we have seen in the section on the current use of EO data. More details will be provided in the "Main players sections" of this analysis. This wide range of products usually aims at managing risk, managing environmental impact, managing social impact, supporting city planning activities or reaching commercial leads.

However, many **local authorities are not yet aware** of the added value of EO data and **public actors as well as environment agencies have restricted budget** with the economic crisis. Even if EO products are money-saving there is a **cultural reluctance** to adopt such products.

Still, more and more municipalities are adopting EO products. Applications that raise a strong interest among local authorities are cadastres and spatial repartitions products. Mapping for monitoring city sprawl and land use is mainly used in developing countries which have no tool to monitor such issues from the ground.

New trends are driving more sustained growth of the market, such as **3D mapping.** Satellite data is particularly adapted to such applications as it provides precise information on the location and temporality of a pixel. Start-ups working in the mapping or change detection areas are developing such applications. In this field, even regular tasks are requiring a much customised work (as opposed to mass-produced applications); it is a **growing specific on-demand market.** Some market players see the future of urban monitoring in **video from satellite** and in **shorter revisit rates** such as for example imagery at different times of the day. A promising sector is also to **detect ground movement for single buildings and individual structures** based on radar data for individuals or private actors.

Disruptive sources of data are also increasingly used, often combined with EO data, such as cell phone signals, street maps, crowdsourcing (mechanism for leveraging collective intelligence of online users), social media, or other remote sensing data using UAVs or drones[211] (useful for small area survey and very local applications). EO data is of better quality, mainly because it is obtained through professional software whereas UAV data relies on less performing software but it may improve in the future. Moreover, EO data is captured by an increasing number of satellite missions and more and more synergies can be observed between the different missions. For example, Synergies between Sentinel-2 and Landsat raises the frequency of the geometrically and radiometrically compatible data[212].

Key Drivers	Key Obstacles
⬀ **Smart cities is a fast-growing market** and EO applications have a key role to play in smart cities, thus are benefitting from this trend. ⬀ The **growing number of sources of data** (crowdsourced, other EO data, etc.) which can be combined with EO data for urban monitoring applications and new products such as 3D mappings or socio-economic information on the population repartition on a territory.	⬂ Many **local authorities have a cultural reluctance** to using EO-based applications. ⬂ The **public end users suffer from budget reduction** and so do not invest in new products such as EO-based applications.

Table 28 - Synthesis of main key drivers and obstacles in Urban monitoring (Source: PwC-Strategy& analysis)

Main players (examples) globally and in Europe

[210] *Marketsandmarkets, 2016. Smart Cities Market by Solution and Services for Focus Areas (Transportation - Rail & Road, Utilities - Energy, Water, & Gas, Buildings - Commercial & Residential, and Smart Citizen Services - Education, Healthcare, & Security) - Global Forecast to 2020.*
[211] *Musakwa, W., Van Niekerk, A., 2014. Earth observation for sustainable urban planning. Trends and future directions. International Journal of Planning Literature.*
[212] *Gomez, C., Ehite, J.C., Wulder, M.A.,2016. Optical remotely sensed time series data for land cover classification: A review. ISPRS Journal of Photogrammetry and Remote Sensing. Volume 116, June 2016, Pages 55–72*

Main players working on urban monitoring include both institutional and private actors, but from our stakeholder consultations we can say that only VAS companies make revenues out of EO applications in urban monitoring.

On the institutional side, generally environmental agencies use EO data. In Europe, as an example, the **European Environmental Agency** (EEA) is the entrusted entity for the development of the Copernicus Land Monitoring Service (CLMS), which provides geographical information to support applications spatial planning, forest management or water management, and is the main institutional actor using EO data for urban monitoring purposes.

On the commercial side, all main VAS companies operating urban services are often working on land and agriculture in general: examples in Europe include **GIM** or **Geoville** as well as more diversified VAS players like **Indra**. **Earth-I** is providing EO-based smart cities applications such as land tenure and cadastre and city infrastructure modelling; they also developed a GIS called ArcGIS, available online. Examples also exist of extreme specialisation on a single class of EO application: one of the biggest players operating in this fashion is **TRE**.

Data flow along the value chain

Data collection and processing platforms

Satellite optical images are used for different kinds of **applications related to mapping**. Often low and medium resolution satellite data (over 10m resolution) is used as a starting point to identify where the information has to be refined, and then is combined with in situ or other kind of remote sensing data, including VHR satellite data. These images can come from **SPOT 5 (down to 2.5m resolution), Landsat (down to 15m resolution), DMC3 (down to 1m resolution), Sentinel-2(down to 10m resolution)**, etc. **Urban Atlas** and **CORINE Land Cover** are used for monitoring urban sprawl and for fragmentation indicators.

SAR data is mainly used for applications such as change detection, it includes data coming from **TerraSar-X, RADARSAT, COSMO-SkyMed, TanDEM-X, Sentinel-1**, etc. The Spanish PAZ satellite is awaited. Historical data used in comparisons to detect changes can come from **ERS, ENVISAT**, the **Japanese agency satellites**, etc.

The **main data processing platforms** used by the different actors is the **CLMS**, which is still under development but on which CORINE Land Cover and Urban Atlas are already available. Other platforms such as **PEPS, ESRI, EODC, Amazon S3 or API** are used by the industry players. **CloudEO**, which is a platform gathering a lot of EO products produced by other organisations, is very useful to find the kind of EO data needed as easy friendly and complete and can help discover new products

Outsourced and in-house capabilities

In the field of urban monitoring, the data processing is mostly outsourced to VAS or GIS companies.

One of the rare examples of in-house capability is for example some business development unit of some chain stores which use EO data for monitoring their expansion.

Development of value-added services, products and applications

EO data, historical data, in situ data and statistical data are combined to build urban monitoring products. For most of the EO applications in urban monitoring, it is necessary to have expertise in both Geographic Information System (GIS) and spatial data processing as detailed below.

GIS is an information system built to capture, store, check, and display data related to positions on the Earth's surface. A GIS allows users to view, understand, question, interpret, and visualise places in a way that it reveals relationships, patterns, trends in the form of maps, globes, reports, and charts. Any kind of data related to a location, including EO data, can be uploaded in a **GIS to analyse; for example, urban surface temperatures or landcover and to find the nature of the correlation between different variables**[213]. For example, companies such as Geosigweb, propose **interactive online GIS** (on which it is easy and fast to add or remove complex elements like roads) for local authorities. Within GIS, EO data is combined with in situ data to cross-check the information.

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[213] *Dousset, B., Gourmelon, F., 2003. Satellite multi-sensor data analysis of urban surface temperatures and landcover. ISPRS Journal of Photogrammetry and Remote Sensing, Volume 58, Issues 1–2, June 2003, Pages 43–54.*

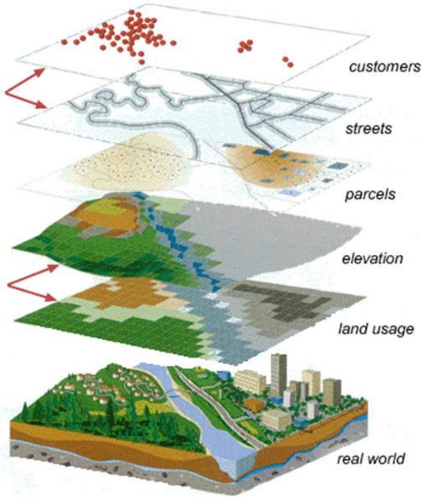

Figure 64 - Geographic Information Systems data combining (Source: Tuah Unggul)[214]

For processing spatial data, techniques are specific to the expected result, below we provide some examples.

Time series data can be used for land cover classification. Indeed, the development of land cover mapping based on surface reflectance data products and the inclusion of time series change in the land cover mapping process makes it possible to obtain information on a class stability[215]

Multiresolution and multiscale analysis, which involve fusing sets of EO images with different spectral band and possibly different resolution, can bring results closer to the reality[216].

Change detection has a lot of different applications such as monitoring urban growth, determining the best route for a metro line, verifying the stability of structure or detecting new constructions or small land-slides in the city. For example, TRE developed SqueeSAR, a tool that they have developed for detecting, measuring and monitoring geophysical phenomena and verifying the stability of structures, and which, in urban areas, is accurate to one millimetre. For such applications**, radar data are compared with historical data**, enabling them to **identify the areas where in situ data is needed and to cross-check the information**. **Multivariate regression models can also be used to model, simulate and predict urban sprawl**.

Some VAS providers are producing urban mappings, building slot mapping and even single building mapping, in order for example to **map with high precision the population density in built-up areas**. In order to do so, administrative data such as **population statistics can be integrated into the mappings**.

For monitoring Urban Heat Islands (UHI) and their negative impact on health and environment, models are developed to **forecast UHI phenomenon and identify the critical areas**. **Vito** is a VAS company which developed such an application which is based on CORINE Land Cover, EEA's Urban Soil Sealing, which will be part of the Copernicus Land Monitoring Service, terrain elevation from the Global Multi-resolution Terrain Elevation Data 2010 (GMTED2010)[217], maps of vegetation cover fraction from MODIS, and in situ data such as temperature measurements. Such products help decision-makers to monitor tree planting for mitigating UHI.

End users

[214] *Tuah Unggul. Geographic Information System. [ONLINE] Available at: http://www.ukurtanah.com/geographic-information-system-gis. [Accessed 21 June 2016].*

[215] *Gomez, C., Ehite, J.C., Wulder, M.A.,2016. Optical remotely sensed time series data for land cover classification: A review. ISPRS Journal of Photogrammetry and Remote Sensing. Volume 116, June 2016, Pages 55–72*

[216] *Ranchin, T., Aiazzi, B., Alparone, L., Baronti, S., Wald, L., 2003. Image fusion—the ARSIS concept and some successful implementation schemes. ISPRS Journal of Photogrammetry and Remote Sensing, Volume 58, Issues 1–2, June 2003, Pages 4–18.*

[217] *GMTED2010 is a global elevation model developed by the U.S. Geological Survey (USGS) and the National Geospatial-Intelligence Agency (NGA).*

The clients eager to pay for data come mostly from the public sector[218], and **local authorities** (e.g. urban planners, city administrators, transport authorities) are the main end users. Other public users are **national governments** (for land administration for instance), **NGOs** (for slum mapping for example), and **international organisations** (e.g. World Bank, EuroGeographics representing the European National Mapping, Cadastral and Land Registry Authorities).

An increasing number of private actors operating in the field of urban monitoring and construction buy EO products such as transport companies, construction companies, energy & utilities companies, real estate agencies, building material suppliers, architects companies, banks and pension funds. Some large chain stores also use such products in order to monitor their development in new cities.

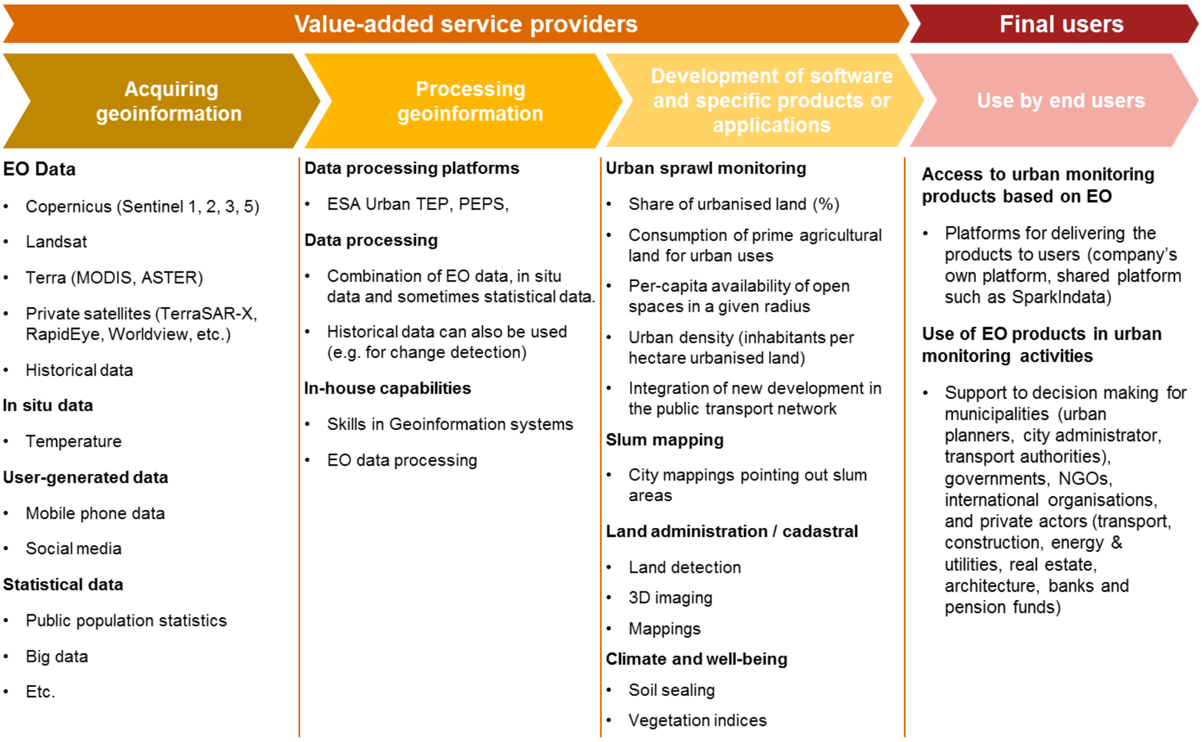

Figure 65 - Data flow along the Urban monitoring value chain (source: PwC-STRATEGY& analysis)

Current role of Copernicus

Copernicus data

Sentinel-1A radar data is used for change detection and constructing 3D models by VAS companies. Sentinel-1A provides continuous all weather, day and night imagery with rapid revisit period in the same imaging mode (6 days), with a wide area coverage (250km swath width) and a millimetre accuracy. Sentinel-1A data can also be used for road and other transportation route mapping.

Sentinel-2 provides relevant data for urban growth monitoring thanks to its high spatial resolution optical imagery.

In the near future, **Sentinel-3** will deliver highly accurate surface temperature products with a two-day global coverage and near-real time products delivered within 3 hours. It will provide additional information to understand and prevent **Urban Heat Islands**.

Copernicus Core services

The **Copernicus Land Monitoring Service (CLMS)** is coordinated by the European Environment Agency and contains four main components: global, pan-European, local and in situ. The pan-European component and the local are the most suited to cities, whereas the global is rather oriented for vegetation, water cycle and energy budget.

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[218] *Noort, M., 2013. Earth Observation for Urban Management, Land Administration, & Spatial Data Infrastructures. Prepared by the European Commission and EO Power.*

The Pan-European components contain products such as **Corine Land Cover** which consists of an inventory of land cover with 44 classes. The Local component contains products such as **Urban Atlas**, which contains detailed land cover and land use information over major EU city areas.

Copernicus Core Service	Products	Application
Copernicus Land Monitoring Service	Pan European component : • Corine Land Cover • European Settlement maps • High Resolution Layers, which provide information on specific land cover characteristics (e.g. on imperviousness), and are complementary to land cover / land use mapping such as in the CORINE land cover Local component : • Urban Atlas (detailed land cover and land use information over major EU city areas)	• Urban planning • Risk management • Environmental and health impact management • Socio-economic impact management

Table 29 - Main Copernicus products related to Urban Monitoring (Source: land.copernicus.eu)

Copernicus socio-economic impact assessment

This impact assessment is based on literature and on the consultation of 18 stakeholders including 12 VAS companies, 4 public actors, 1 non-profit association and 1 research centre.

Copernicus current enabled revenues

According to EARSC, the EO downstream revenue attributable to "urban areas" is approximately 5% of the total, which is equal to a value of EUR 45.5 million in 2015.

According to stakeholder engagements[219], the minimum proportion of Copernicus data to total EO data used is about 10%. Hence, a conservative estimate of the **value attributable to Copernicus data within urban monitoring is EUR 4.55 million in 2015**. Within the EO downstream revenues, however, this estimate is likely to be a lower-bound. Copernicus data on average is valued higher than non-Copernicus, EO data. This is due to the additional advantages of using Copernicus data in applications for urban monitoring. Hence, the actual value of Copernicus for VAS actors is likely to be higher than the share of Copernicus in EO data.

A more optimistic approach consists in considering the wider GIS market as a basis for the intermediate users benefits. According to Technavio[220], the European GIS data and services market represented EUR 1.34 billion in 2015. Assuming the share of urban monitoring in the GIS market equals the one in the EO market - i.e. 5% - and the share of Copernicus within the urban monitoring GIS market equals our conservative estimation of 10%, it can be estimated that **the benefits of Copernicus on the GIS data and services market were around EUR 6.69 million in 2015**.

To extrapolate the results up to 2020, it is assumed that the revenues generate by EO in the field of Urban Monitoring will grow at a rate driven by both the growth of the overall EO data market (estimated to experience a CAGR of 14.11% over 2015 – 2020) and the growth of the smart cities market (which is estimated to grow by 19.4% per annum between 2014 and 2019[221]). The share of Copernicus data among EO data is assumed to remain constant. It can be noted that these assumptions may even be lower-bounds as, according to EARSC, the market of EO in the field of urban monitoring grew by 79.55% per annum between 2012 and 2015.

[219] *With a sample size of three companies.*
[220] *Technavio, Global GIS market 2016 - 2020*
[221] *Technavio, Global Satellite-based Earth Observation Market, 2016 – 2020; MarketsandMarkets, 2016. Smart Cities Market by Solution and Services for Focus Areas (Transportation - Rail & Road, Utilities - Energy, Water, & Gas, Buildings - Commercial & Residential, and Smart Citizen Services - Education, Healthcare, & Security) - Global Forecast to 2020.*

(M EUROS)	EO downstream market for urban monitoring	% of Copernicus enabled revenues (conservative)	Copernicus benefits for intermediate users (conservative approach)
2015	45.5	10%	4.55
2020	98.7	10%	9.87

Table 30 - Copernicus enabled revenues for the urban monitoring intermediate users (source: PwC-STRATEGY& analysis)

(M EUROS)	GIS data and services market for urban monitoring	% of Copernicus enabled revenues	Copernicus benefits for intermediate users (optimistic approach)
2015	66.85	10%	6.69
2020	104.40	10%	10.44

Table 31: Copernicus current enabled revenues for urban monitoring intermediate users – based on GIS market (source: PwC-Strategy& analysis)

The third type of benefit from Copernicus impacts end-users. A Cisco study shoes that for a city of 1.2 million inhabitants, the ROI of investment in smart cities products is 25%[222]. Considering that the investment equals the Copernicus enabled revenues for the downstream sector calculated above. This gives us the following figures.

(M EUROS)	Conservative estimate	Optimistic estimate
2015	1.14	1.42
2020	2.76	3.45

Table 32: Copernicus enabled revenues for end users in the field of urban monitoring (source: PwC-STRATEGY& analysis)

The Figure 66 sums up the conservative and optimistic scenarios, aggregating intermediate users and end users benefits.

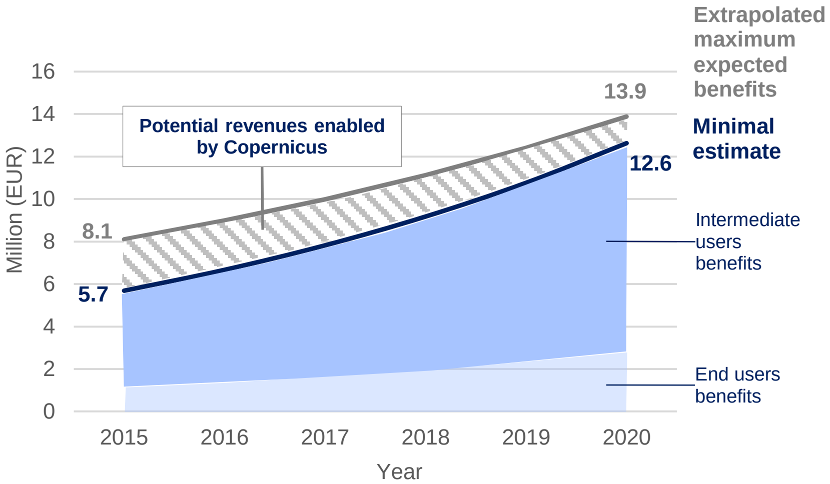


Figure 66: Different scenario estimates of the revenues generated by Copernicus in the field of urban monitoring (source: PwC-Strategy& analysis)

However, these results have to be treated with caution. Indeed, the scale of Copernicus value added is complex to estimate. The services that potentially benefit from urban monitoring are vast, covering sectors such as land use and land cover, research and development, and public services. It is difficult to establish a suitable number to approximate the size of these components as a proportion of urban monitoring activities, and by extension, Copernicus data's contribution to those activities.

Such Copernicus downstream revenues in the field of urban monitoring suggest that it is worth investing in Copernicus. Indeed, the use of Sentinel-1A data has generally required investments in specific hardware and software and required hiring highly skilled people. **As an example, a VAS company specialised in urban**

[222] *Cisco, 2014. Smart and connected communities. Solutions for a Smart city. EMEA.*

products reported having to spend EUR 150.000 (about 3% of their turnover) specifically for using Copernicus data.

Indeed, Copernicus has a **strong value added for change detection**. In particular, Sentinel-1A is providing radar data with a resolution and extensive cover that was not available before and for which there is no competition from other technologies. Thus, **it enables the development of new products** enabling for example the detection of slow landslides based on Sentinel-1A historical data.

Sentinel-2 provides data with a resolution which is too low to be used as main source of data for urban monitoring applications. However, **it is a key cost- and time-saving tool in a multi-scale approach** which means that Sentinel-2 is the first data used in the process, sometimes combined with other kind of data, to identify the major infrastructures and for material classification, and thus to select the areas where costly VHR data should be used.

Using Copernicus data has had a **strong effect on the development of competences**. A VAS company estimated that processing Copernicus data has resulted in a strong increase of competence which provides them with a competitive advantage, especially in comparison with American competitors.

Copernicus also has a **strong network effect**, as illustrated in the following examples:

- Winners of the Copernicus Masters (e.g. Building Radar in 2015) have reported that it significantly expanded their network, in particular at the early stages of a start-up.
- SparkIndata is an example of partnerships between VAS companies based on Copernicus data: it helps to better promote EO products for local authorities, and brings industrial recognition to the smallest players. One of the VAS companies consulted for this analysis is **expecting revenues of between EUR 300,000 and EUR 2.5 million entirely attributable to the project, representing, at a minimum, 30% growth in its total revenues.**
- Using Copernicus also gives the opportunity to SMEs to partner with major industry players such as Airbus.
- Urban Atlas has also created a community of users. Investors are more willing to participate in projects which use Copernicus.

Using Copernicus is also generally considered as a **competitive advantage in the sales speech** to local authorities by the intermediate actors consulted for this analysis, especially in developing countries where they trust the programme because it is produced by the European Commission (it is less the case for private actors which are more interested in the results than on the data that is used). As Copernicus provides identical and comparable data all over the world, it opens up new prospects for VAS companies, in particular abroad.

Over the period 2015 – 2020, Copernicus-enabled revenues in the urban monitoring value chain are forecasted to support a cumulated total estimated at **between 430 and 550 person years** in Europe. Most of the supported jobs are within the EO downstream market, with between 320 and 400 person years.

It is assumed that productivity among the end users in the urban monitoring was the same as for the industry NACE 84.11 and that productivity among the intermediate users was the same as for the industries NACE 62.01 and 62.02. The enabled employment estimation method used employment, output and GVA data from the Eurostat National Accounts (for NACE 84.11) and employment, turnover and GVA data from the Eurostat Structural business statistics (for NACE 62.01 and 62.02). The 2020 estimates were based on E3ME growth projections for these variables.

Non-monetary benefits of Copernicus

Urban products based on Copernicus provide sound social benefits. Urban Atlas ensures a VHR mapping **for urban sprawl monitoring** of the main European cities as well as of artificial surfaces (e.g. roads), helping to monitor the various issues linked to the phenomenon. For mapping applications, SMEs used to analyse SPOT 5, Landsat or even IGN data but they had **issues of repeatability which are solved with Copernicus data.** More specifically, the **Sentinel-2 has a short revisit time and ensures long-term continuity** so it improves urban growth monitoring when the data are duly used[223].

As an example, based on the cost-effective multiscale approach using Copernicus, the VAS company GIM, expert in remote sensing, managed to **map all slums in the city of Manila in the Philippines** in order to estimate the density of the population of these areas. They reached a particularly high level of precision allowing them to detect all the slums and to classify them, and it turned out that **27% of the detected slums were pocket slums that have never been identified**.

Copernicus urban products also have considerable benefits from an environmental standpoint. They can include low resolution biophysical variables such as land surface temperature and the relevant data to produce high-resolution maps of artificial surfaces for example, which **help monitoring Urban Heat Islands (UHI),** and the related negative impacts on health (heat strokes, syncopes, quality of the water, etc.), local climate (e.g. increasing rainfalls), animals and plants up to 10km around the city, and increasing energy usage for air conditioning and refrigeration[224].

[223] *Noort, M., 2013. Earth Observation for Urban Management, Land Adminsitration, & Spatial Data Infrastructures. Prepared by the European Commission and EO Power.*
[224] *ESA, EC, 2013. Satellites help to design more habitable cities.*

CASE STUDY

Copernicus for early detecting and remote monitoring of construction sites with the start-up Building Radar

Presentation of the project

Building Radar is a German start-up, operational since April 2015, which **supplies verified construction sales leads worldwide** providing information such as a construction site location, the construction phase, the building size, the companies involved and a lot of other data on construction projects. The clients are any company related to buildings such as construction companies, real estate agencies, building material providers, electricity providers, etc. There is a wide range of applications that provide a competitive advantage to their users such as tracking competitors' next moves, evaluating strategic partnerships, assessing with accuracy the value of an asset, remotely follow the progress of a construction site, etc. The products are delivered on a user-friendly platform (website and application) in the form of a search engine, as illustrated in the following figure. They propose a general service and on-demand customised services, for example for a specific query over a specific region, to perfectly meet the needs of their clients. The information on leads from all over the world gets updated at least all 24 hours providing its clients with automatic, reliable, detailed and up to date information to the client's preference.

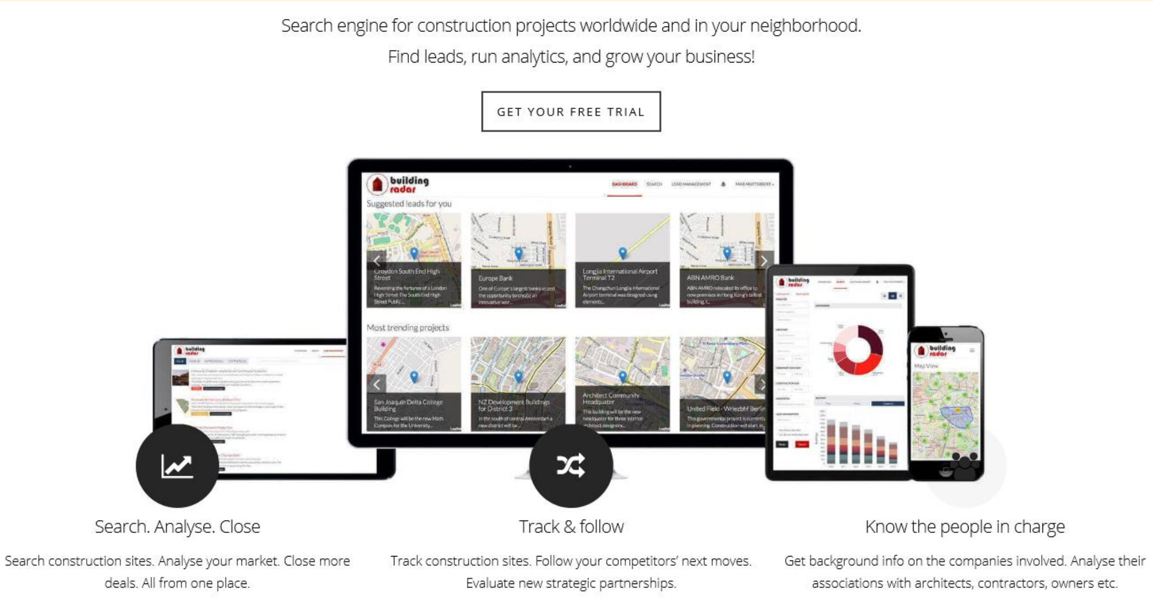


Figure 67 - Building Radar search engine's possibilities of use (source: https://buildingradar.com/)[225]

Building Radar estimates the world market for sales leads in the construction sector at more than EUR 70 billion. **Their monthly turnover is comprised between EUR 10K and EUR 50K** and their **target growth rate is 30% month to month.** They are planning to develop their business in the US and in China this year.

One of the applications of Building Radar aims at **monitoring construction along all the phases of a construction site**. It enables the construction companies to have an **immediate overview of the progress of the works** and identify potential issues in advance. Building Radar also stores the history of photos of the construction site in order for the client to be able to **compare the effective progression of the work with the planning.**

Their services cost from hundreds to thousands, up to in some cases tens of thousands of euros per months so it should be affordable for all sizes of players.

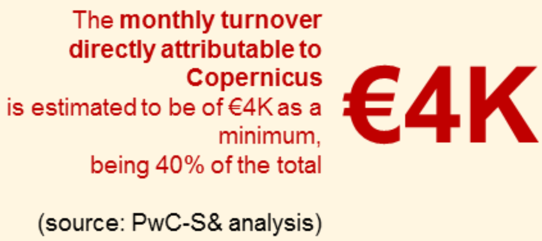
[225] *Building Radar. 2016. Product. [ONLINE] Available at: https://buildingradar.com/. [Accessed 16 June 2016].*

Building Radar relies on the one hand on EO data, in particular on Copernicus, and uses no in situ data, and on the other hand on Internet data processed through their algorithms. They process 2000TB per annum and they follow more than 130,000 web page sources and more than 3 million construction projects.

Copernicus enabled revenues

Building Radar could not have existed without Copernicus because they could not have afforded fee-based data, especially as **Copernicus accounts for 60% of the satellite data** they use so the fact that **Copernicus data is free has been decisive and their business model entirely relies on it**. Then, Copernicus perfectly meets their needs in terms of data. Indeed, **Sentinel-2 RGB bands enables the detection of new constructions and to remotely monitor a construction site** as its main value added is its frequency of the updates, which ensures a regular control on the ongoing constructions. **Building Radar is awaiting Sentinel-2B data** as the frequency of the updates will drop from 10 days to 5 days, which could **improve their product and enable them to reach new clients**. Furthermore, **Copernicus has boosted their business several times and helped them develop the right network**: first, their participation to ESA App Camp resulted in an international collaboration with SAP for the development of their platform and second, they were "Overall winner" of the Copernicus Masters 2015 which helped them increase their visibility.

Today, **40% of their clients use applications which rely on Copernicus data** and those needs could not have been met without the European programme, the other 60% rely solely on Internet data processing. It then may be inferred that a minimum of EUR 4,000 (40% of the minimum turnover estimation) of monthly turnover is directly attributable to Copernicus.



Building Radar is continuously improving its product. They are currently working on their software to make it automatically detect changes on the images so that the clients would save even more time as they would not need any more to review all the last months' images. Building Radar is also **assessing Sentinel-1 data in order to see through the cloud cover and provide information on the progress of a construction through elevation models.**

As Building Radar planned turnover growth rate is of 30%, that today 40% of their turnover is directly attributable to Copernicus and that in the future this percentage should not decrease, and actually is rather expected to increase with the release of Sentinel-2B data and the possible use of Sentinel-1, we can make a minimum estimation of the monthly turnover directly attributable to Copernicus for the upcoming year as illustrated in the following figure.

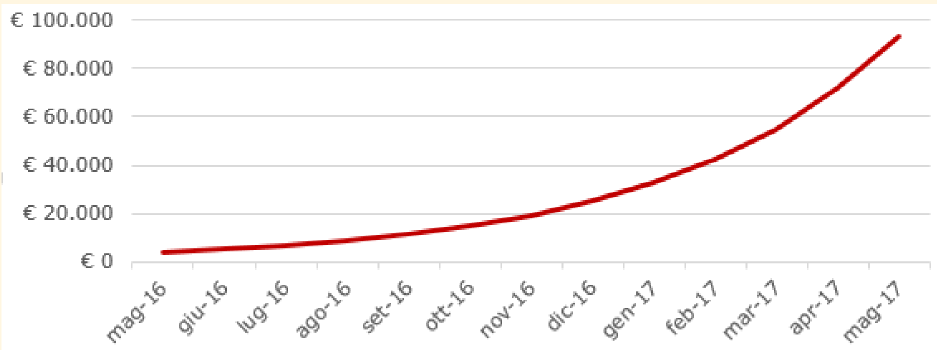


Figure 68 - Estimation of monthly turnover directly attributable to Copernicus for the upcoming year (source: PwC-STRATEGY& analysis)

Building Radar enabled its clients to increase their turnover, their sales performance and gain time. For example, the remotely monitoring of construction sites application enables the entrepreneurs in charge of the construction site to **save time and money by drastically limiting unnecessary travels on site as they can remotely control their construction sites**. A survey conducted by Building Radar revealed that on average, for all their applications and types of clients, **Building Radar enables its users to save 3 hours per day and EUR 60,000 per year.** Below are presented a few examples of stories of clients operating on various markets, and the detail on the attributable share of Copernicus in their success based on Building Radar products**. The benefits of using Building Radar presented in the following customer stories are attributable at 100% to Copernicus as they are clients using applications which rely on Copernicus.**

Stanko Team, a flooring supplier operating on the German market had for a long time been searching for affordable ways of getting leads for construction projects according to their specifications. Traditionally, they hired consultants or relied on paper directories, but this proved to be **five time more expensive than Building Radar solution and the results were poor.** Building Radar has provided them with several thousand current, new, completed and proposed projects on their market. Building Radar's satellite technology based on **Copernicus, also helped them save 8 hours of driving and examination per project**. Real-time images mean they can avoid site visits to check on construction progress. Instead, they could invest that time in profit generating projects[226].

Gerhardt Braun, a medium-sized enterprise in the construction sector, is also client of Building Radar. Since the first months they started to use their platform, **Building Radar's product increased their sales performance by 14% every single month**. They also use Building Radar to assess new market opportunities and to do market research. In former times, they had to use several expensive tools to do this work and the employees were struggling and wasting time using such software which were hard to use. **Thanks to Building Radar their research projects are finished on average 30% faster** and hence they managed for the first time to complete projects under budget. Building Radar also enabled them to deliver better quality as they can totally rely on the platform instead of combining the information providing from different sources[227].

Fundoland is a company operating in the amusement industry based in China on the world market who is also client of Building Radar. Building Radar provides them with construction projects in over 100 countries, with a specific focus on Asia, their primary market. Building Radar allowed them to **save 50% of their time and to focus on the right clients from the beginning of the sales process, and by giving them extra indications** as to when they should make bids for relevant projects. They are now more aware of developments in their target market as well as of their competitors. **Their sales have grown by 30% since we started using Building Radar.** It enabled them to **automate their lead generation process and to reach 150% more leads every day**[228]**.**

Luxadd is a lighting solution with substantial cost savings for potential customers who started with no customer base. Building Radar enables them to reach the customers they knew would benefit from their products. **Building Radar drove about 80% of their sales** and helped them understand their portfolio of clients. **Building Radar helped their sales team really cut down to 0 sales leads research time**; and focus entirely on converting leads instead. They have then been able to **establish a strong customer base with some new 350 leads monthly in their target region**, but also to reach new clients in other industries, realising the true potential of their product[229]**.**

Other opportunities raised by Copernicus

While developing Building Radar, the team members have increased their own competences in satellite data processing and they have the opportunity to train interns to Copernicus data processing techniques.

Building Radar is assessing the opportunity use Copernicus to help cities become greener. One application could be to identify the roofs which have the size and the direction adapted to be equipped with

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[226] Building Radar. 2016. Leads for flooring suppliers Stanko Team. [ONLINE] Available at: https://buildingradar.com/product/customer-stories/construction-leads-for-flooring-suppliers/. [Accessed 20 June 2016].
[227] Building Radar. 2016. Leads for Room System Solutions Supplier Gerhard Braun GmbH. [ONLINE] Available at: https://buildingradar.com/product/customer-stories/construction-leads-partitions-room-system/. [Accessed 20 June 2016].
[228] Building Radar. 2016. Leads for Amusement Industry company FundoLand. [ONLINE] Available at: https://buildingradar.com/product/customer-stories/construction-leads-for-amusement-industry/. [Accessed 20 June 2016].
[229] Building Radar. 2016. Leads for lighting company LUXADD. [ONLINE] Available at: https://buildingradar.com/product/customer-stories/construction-leads-for-lighting-industry/. [Accessed 20 June 2016].

photovoltaic panels and another idea is to identify green roofs in a city which could of interest for horticulturists. Indeed, Sentinels are particularly adapted to such applications as they not only provide conventional optical images but also information via coloured channels and heat radiations through infrared radar images.

Copernicus projected contribution to the global and European socio-economic impacts

According to our conservative estimate, the **expected value of Copernicus data by 2020 is EUR 13.80 million**. However, Copernicus data will likely grow in importance (and in value), with the provision of, for example, land-surface temperature information.

Sentinel-3 is expected to provide highly accurate land-surface temperature information with two-day global coverage and real-time products delivered within three hours, which will **help planners identify the UHI and take the right decisions for making cities more energy-efficient.** Its **short revisit time will improve the accuracy of the EO-based products**.
A VAS company specialised in change detection has estimated that **20% of its revenues is expected to be reliant on Copernicus in 2017**. Sentinel-1A can be used for screening large areas and for increasing the number of data available on a specific area. Sentinel-3 will also enable the **creation of new products on a large scale for monitoring regional areas**. While Sentinel-1A is already supporting road planning activities, Sentinel-3 will go one step further, by providing high resolution altimeter-derived elevations acquired over land surfaces, thereby optimising the cost and efficiency of road planning[230].

Going a step further, the development potentialities of UAVs for smart cities, used in conjunction with Copernicus data, can have a wide range of applications for geospatial surveying (e.g. traffic management)[231].

In addition, the development of the ESA Urban Thematic Exploitation Platform (TEP) and the fact that Sentinel-2 data has only recently been made available on the market are good reasons to anticipate an **increase in the number of users for urban monitoring purposes**. The ESA Urban TEP, still under construction, will offer **a global map of human settlements** at a spatial resolution of 12 metres per grid cell (aggregated to 75m for public use). New products include the Global Urban Footprint, a global map of human settlements at a spatial resolution of 12 metres per grid cell (aggregated to 75m for public use). In the beginning, the data will come from the German radar satellites TerraSAR X and TanDEM X, but should integrate Copernicus data in the future[232]**.** In particular, **Copernicus Climate Change Service (C3S) is under development but will soon disseminate products dedicated to cities** that will enable planners to monitor cities environmental impact, increasing the number of users of EO data for sustainable development purposes. **Sentinel-3 and Sentinel-5B** data will also be key to develop environmental applications.

Economic	• Copernicus downstream market in the field of urban monitoring is estimated to have been worth EUR 5.69 million in 2015 (conservative approach) • Sentinel-1A enables the **development of new products** in urban monitoring (e.g. to monitor construction sites) • Sentinel-2 makes the VAS companies **save time and money** as it helps using expensive VHR data only where it is required • Consulted VAS companies estimate that at least **15% of their revenues in EO** urban monitoring is directly attributable to Copernicus • Copernicus programme has **strong network effects**, encouraging partnerships between VAS companies to coordinate their efforts, some expecting **10% of growth** from such initiatives • Copernicus helps VAS companies to **find funds** • Copernicus opens new development opportunities for urban monitoring EO-based products, in particular it is a selling point in developing countries • Copernicus allows a more cost-effective management of the cities

[230] *Copernicus, 2014. Keeping Europe on the move. Prepared by ESA and the European Commission. February 2014. No. 40.*
[231] *Mohammed, F., Idries, A., Mohamed, N., Al Jaroodi, J. and Jawhar, I. 2014. UAVs for Smart Cities: Opportunities and Challenges. Paper presented on the International Conference of Unmanned Aircraft Systems (ICUAS). Orlando, Florida, USA.*
[232] *Thematic exploitation platform. 2015. About the TEP initiative. [ONLINE] Available at: https://tep.eo.esa.int/about-tep. [Accessed 20 June 2016].*

	• Sentinel-3, with the provision of highly accurate land-surface temperature information and its short revisit time, will **improve accuracy** of existing products and enable the **creation of new products** (expected) • The development of potentialities of UAVs and other types of data compiled with Copernicus data will give birth to **new smart cities products** (expected)
Social	• Copernicus improves urban sprawl, urban growth and infrastructures monitoring, contributing to **maintain a good quality of life and access to public services in all parts of the cities** • Copernicus helps to identify social issues and design customised solutions to efficiently monitor cities • Copernicus **increases companies' competences (up to 80%** for companies interviewed within this study) • Sentinel-3 will enable the **monitoring of regional areas** (expected)
Environmental	• Copernicus helps with **forecasting and preventing Urban Heat Islands**, mitigating their negative impacts on health and environment • Sentinel-3 will help planners to make cities **more energy-efficient** (expected) • Copernicus and in particular C3S will improve the management of the environmental impact of cities (expected)
Strategic	• Having competences in using Copernicus is a **competitive advantage**

Figure 69 - Synthesis of Copernicus impacts – Urban monitoring (Source: PwC-STRATEGY& analysis)

Voice of Copernicus' users[233]: SWOT

STRENGHTS

- The quality of Copernicus data enables a lot of applications for cities
- Sentinel-1A is the first satellite that has been specifically designed to disseminate radar images which cover large areas and that enable the comparison of different ranges of values taken at different times
- EO is often the best available source of data for urban monitoring in developing countries
- Copernicus enables the creation of partnerships which organise the supply for local authorities (e.g. SparkInData)

OPPORTUNITIES

- Emergence of advanced algorithms such as image fusion to extract data from satellite imagery, greater computational power, and other advances in technology open new opportunities for urban remote sensing applications
- UAVs data will improve in the future, creating more opportunities for applications based on both Copernicus and UAVs data
- SMEs developing urban products benefit from R&D partnerships with other SMEs abroad

WEAKNESSES

- Technical limitations include the spectral, geometric, textural, and contextual complexities of urban areas which make it difficult to extract target figures
- There are limited time windows during which the EO data can be provided
- The InSAR market, useful for urban products, is developing slowly because contrary to the navigation market, it has been developed by small players and there are no clear sponsors. This is why, even if the technology and the algorithms are ready, it is still difficult to get the right space segment
- Satellite imagery often come with licensing restrictions which inhibit local authorities
- Local governments are lacking resources well-trained to use urban EO-based products

THREATS

- Public actors have very little budget to invest in the use of EO data. This observation is to be coupled with a more "cultural" obstacle: the acceptance to adopt this new technological mean is often described as a long institutional process
- UAVs data quality will improve in the future and will compete with EO data in a market that is increasingly specific.

233 *PwC-STRATEGY& analysis, on the basis of interviews conducted in 2016 (cf. detailed list of interviewees in the appendices)*

Policy recommendations to foster urban monitoring through Copernicus

Strategic pillar	Sectoral recommendations for policy action	Priority level
Pillar I: Ensure access to data	***#UM-1 – Coordinate the relations and improve the dialogue between the different stakeholders*** Copernicus ecosystem is perceived as rather fragmented and thus difficult to approach by local authorities or SMEs operating in urban monitoring. Better coordination of the activities of the different institutions involved in the Copernicus programme would facilitate access to Copernicus data and services.	3
Pillar II: Support innovation	***#UM-2 – Encourage partnerships between VAS companies*** Copernicus produces a huge volume of data so, in order for cities to maximise the benefits of such a programme, institutions could encourage partnerships of VAS companies to process and disseminate this data for urban monitoring applications.	3
Pillar II: Support innovation	***#UM-3 – Communicate on the availability of Copernicus data to help monitor cities*** Having greater visibility for Copernicus products in the pipeline (when they will be available, for which geographical zone, etc.) would help VAS companies to better anticipate the development of VAS products for specific towns.	2
Pillar II: Support innovation	***#UM-4 – Create more synergies between EO-funded projects and ICT-funded projects*** Connections could be made between EO projects and ICT projects in the frame of smart cities in order to leverage synergies, identify the opportunities and create a flourishing market.	3
Pillar II: Support innovation	***#UM-5 – Produce a standardised processed dataset*** A standardised processed dataset could help avoid duplicating the processing work among different actors. It would enable urban stakeholders to save time and budget and would facilitate comparisons between cities in the world.	2
Pillar III: Increase awareness and use	***#UM-6 – Advertise EO applications for urban monitoring to the local authorities*** Organising a campaign to clearly communicate to local authorities the benefits of EO VAS for urban monitoring and how to use such services could be a way to break cultural barriers, provide the right tools to maximise the benefits from such products and demonstrate how they lead to time and money savings.	1

Insurance related to natural disasters

Key specificities
➢ (Re)insurance is a mature economic sector of non-EO experts, with some very specific needs for EO and GIS products. ➢ The applications for EO (property insurance) are linked to natural hazards, crops insurance and livestock insurance. ➢ For risk modelling and loss assessment activities (majority), EO is a complementary source, not critical and with a moderate added value. ➢ EO is a critical source for the development of index products for crops and livestock insurance. ➢ EO exploitation reveals opportunities for costs reductions on existing insurance policies and processes, as well as the development of new addressable markets (fodder insurance, and livestock insurance in developing countries). ➢ Insurers are interested in end-information, exploitable inputs for their activity rather than raw data. ➢ Few players have in-house capabilities for ad-hoc EO data manipulation and the majority acquire EO products and services from 3rd party companies. ➢ Strong variations exist in the maturity of the use of EO between (re)insurance companies, independently from the size of the company. ➢ (Re)insurance applications face technical challenges for the development of reliable index products.

Scope/boundary

In this section the benefits of EO data for the insurance sector are analysed.

The insurance sector is very wide, covering both life and non-life insurance. This report focuses on the insurance industry that can be impacted by and benefit from EO data, **exclusively property insurance**, within non-life insurance.

As of 2016, EO data is exploited by the insurance sector for **hazards linked to natural disasters only**, and there are no forecasts for it to be used for other types of insurance policies, such as health or casualty insurances. The use of EO data investigated in this chapter includes all practices and methods of (re)insurance companies, from the definition of insurance premiums to the indemnities payments, for policies covering material damages and losses caused by natural disasters.

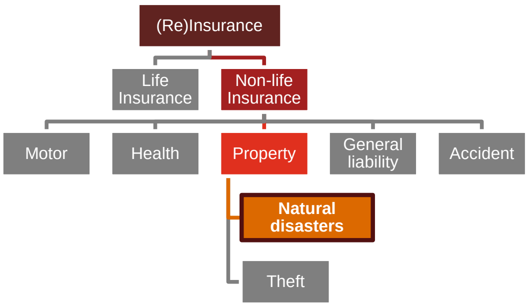

Figure 70 - Natural disasters insurance within the insurance industry

Depending on the insurance policies and the (re)insurance company, the hazards included in natural disasters can vary. It's worth noting that they do not only include large-scale, intermittent, violent events such as hurricanes and large floods, but also more progressive, local and subtle changes such as frost or droughts, as soon as they can be damageable to insurers' clients. The analysis conducted here encompasses all types of natural disasters encountered through the interviews and the literature review, as detailed hereafter in the chapter *Value chain description - Impacts of natural disasters*.

Taxonomy and definitions

Main definitions related to the insurance value chain	
Insurer (or prime insurer)	A company that provides risk transfer mechanisms whereby risks are assumed by third parties. Insurance is a financial product that legally binds the insurance company to pay losses of the policyholder when a specific event occurs. The insurer accepts the risk that the event will occur in exchange for a fee, the premium[234].

[234] *Source: The Council of Insurance Agents and Brokers, The Role of Insurance Intermediaries, www.ciab.com/uploadedfiles/resources/roleofinsint.pdf (retrieved 06/06/16)*

Reinsurer	Reinsurance is insurance for insurers. Insurers buy reinsurance for risks they cannot or do not wish to retain fully themselves.[235]
Insurance policy	A formal contract issued by the (re)insurer to its client, which puts into effect the coverage (legal evidence), and specifies the terms of the coverage including the risks covered and the amount of the premiums[236]. Other information is included but is not relevant to the analysis conducted in this study.
Insurance premium	A series of regular payments from the policy holder to the insurer in exchange for the protection against events[237].
Catastrophe modelling	A risk management tool that uses computer technology to help insurers and reinsurers as well as business and government agencies better assess the potential losses caused by natural and man-made catastrophes[238].
Loss assessment	Activity performed by a (re)insurance company to evaluate the amount of damages undergone by its clients. The aim is to define the amount of indemnities to be paid off by the (re)insurer, depending on the terms of the insurance policy contracted.
Index product (or parametric product)	This type of insurance does not indemnify the pure loss. In Parametric insurance, the pay-out of the insurance policy is calculated using a model that shows the actual damage on the ground. This system provides payments in a shorter period of time compared to traditional insurance system, because it does not rely on loss adjusters to assess the damages.[239]

Value chain description

Overview of industry/domain

Key figures - *European property insurance weighed EUR 92 billion in 2014, growing by 2% since 2013.*

In 2014, the European insurance and reinsurance premiums accounted for 35% of the global market. The revenues for the European market were estimated at around **EUR 1170 billion** by the European insurance and reinsurance federation, Insurance Europe, representing approximately **8% of the total GDP of the European Union**[240]. These revenues were generated by about 4860 insurance companies, most of them being joint stock companies and mutual insurers.

Out of the total revenues, 39% (EUR 455 billion) was generated through **non-life premiums**. According to the European Insurance and Occupational Pensions Authority (EIOPA), this market has displayed relatively stable growth of between 4% and 5% per year since 2010 (with an occasional slowdown in 2014 to around 0%)[241]. Out of the non-life insurance market, **property insurance** accounted for 20% (EUR 92 billion) in 2014, growing by 2% compared to 2013[242].

In terms of employment, the insurance and reinsurance sectors employ about **1 million persons in Europe**.

Insurance and reinsurance principles - *risks transfer, risk modelling, claim-based and parametric schemes*

In the analysis conducted in this chapter no specific differentiation is made between the insurers and reinsurers activities as they are both based on the same principle. The only difference is that in the case of a reinsurance contract, the ceding company is a primary insurer rather than an actor outside the insurance sector (individual or a business). Reinsurance is particularly used when potentially important losses can occur in a short time period (typically for natural disasters insurance), since the reinsurance system enables the "spreading" of the cost and risks between several types of actors.

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[235] Source: Swiss Re, Understanding reinsurance: how reinsurers create value and manage risk
[236] Source: http://www.businessdictionary.com/definition/insurance-policy.html (retrieved 06/06/16)
[237] Source: Aditya Challa, Insurance models and risk-function premium principle, 2012
[238] Source: Insurance Information Institute, www.iii.org/article/catastrophe-modeling-vital-tool-risk-management-box (retrieved 06/06/16)
[239] Source: Earthquake Engineering Research Institute, www.eeri.org/parametric-insurance (retrieved 06/06/16)
[240] Source: Insurance Europe, European insurance key facts, 2015 ; CIA, The World Factbook - retrieved February 2016
[241] Source: EIOPA, Financial stability report December 2015
[242] Source: Insurance Europe, European insurance key facts, 2015

Insurance and reinsurance business relies on the principle of **risk transfer**. In non-life insurance, a (re)insurer has a contractual obligation to be able to bear the risk of future losses in return for a **premium**. In order to do so, he must be able to assess the risk as accurately as possible, by assessing the **expected annual losses** of the insured product, which impacts directly the premium value, and the **extreme event losses**, which provide information about the amount of capital that should be detained by the company in order to face an extraordinary catastrophe event.
The process to define insurance premiums starts with the assessment of the type of risk incurred[243]:

- **Idiosyncratic risk** defines a situation where an individual exposure is not related to its neighbour's exposure.
- **Covariate risk** defines the case where a cause affects neighbouring individuals at the same time. This is especially the case for **natural disasters insurance**.

For each type of natural hazard, the risk is converted into **potential losses**, depending on 3 parameters:

- The **occurrence** frequency, defining the number of times the event will occur,
- The **event size**, defining the damages suffered during the event,
- The **location** of the insured object, defining its vulnerability to the event.

The conversion of risks into potential losses is achieved through the definition of risk models, which can be either created internally by (re)insurers or provided by specialised companies. EO data can contribute to the improvement of these risk models and to their calibration and validation.

From the evaluation of the potential losses, (re)insurers then define the premium level for each risk. This premium definition depends on various parameters including the pricing strategy of each (re)insurance company. This aspect is the cornerstone of the business model of (re)insurers, linking the competitiveness of the insurance policies to the economic viability of the product, which is roughly reflected in the ratio between the value of premiums received and the total insured value.

The payments to be made by (re)insurers were traditionally defined by the claims received from their customers. In the early 2000s, an alternative approach to the traditional claim-based scheme appeared on the market, allowed by the exploitation of EO data. This alternative scheme, based on index products, is applicable to a limited range of activities. However, it constitutes a proper business model and today both types of insurance can benefit from EO images. The basic principle of each model is the following:

- For **claim-based insurance** ("classical" scheme), the insurer pays an indemnity after receiving a claim of loss from its customer. This traditional model induces high costs related to prospecting for policyholders, negotiation of contracts, verification of losses (by commissioning experts on the field after the event to assess the losses) and determination of pay-outs. **In this scheme, EO data stands as a complementary source** only, as claim-based insurance has been existing for decades before the availability of satellites images, relying on other data such as meteorological institutes.
- For **index insurance** (also called parametric insurance), customers are indemnified based on the computation of an index related to the insured losses, which is compared to a threshold to define the level of indemnities. This innovative model is applied to particular types of insurance, mostly for agriculture (fodder yields), and for livestock insurance. **It was enabled by the use of EO images** and today very different levels of maturity exist within (re)insurers regarding its commercialisation.

Index insurance offers several advantages: it allows **costs reductions** by suppressing the verification step and it avoids the frauds and moral hazards which are frequent in claim-based insurance (and leading to an increase in the premiums). The payment according to a threshold also reduces the **delays for the payment** and can potentially be automated to increase the costs savings.

In this system however, some customers may not receive any payment despite incurring actual losses, while others may receive indemnities despite incurring no actual losses. In order to remain attractive and profitable, it is in the interest of (re)insurers to have a **good correlation between the index value and the actual losses suffered**. This underlines the technical challenges for EO data exploitation.

Impacts of natural disasters *- Losses per year in Europe over EUR 12 billion and increasing, less than half are insured*

As of 2016, the activities of (re)insurers benefiting from EO data are all related to natural hazards. If insurers are unable to avoid or reduce the disasters, an accurate forecasting of threats and risks can help mitigate the

[243] *Source: MDPI, The Potential and uptake of remote sensing in insurance: a review, 2014*

damages among the population and the economic losses. From the customers' perspective, insurance is a means by which to be protected against an abrupt material loss, which can have invaluable consequences.

Hazard	Major impact
Storms, snow avalanches, landslides, earthquakes, volcanos	Economic losses, human fatalities
Forest fires, floods	Economic losses, human fatalities, ecosystem degradation
Water scarcity and droughts	Economic losses, ecosystem degradation
Extreme temperature	Human fatalities
Oil spills, industrial accidents, toxic spills	Pollution of ecosystems

Figure 71 - Type of impacts by type of natural disaster (Source: EEA, Mapping the impacts of natural hazards and technological accidents in Europe, 2010)

Over time, the growth of the world population and the development of highly concentrated areas resulted in increased impacts of natural events, mostly regarding human and material losses (other hazards such as oil spills and industrial accidents have an impact focused mainly on the ecosystem). **At a global scale, damages of natural disasters have regularly exceeded USD 100 billion per year** in recent years, reaching over USD 360 billion (of losses) in 2012 with the earthquake and tsunami in Japan[244]. The two most affected countries, Japan and the US, have experienced approximately USD 40 billion of losses per year since 2001, reflecting the geographical vulnerability of Asia to earthquakes and floods, and of America to storms and hurricanes.

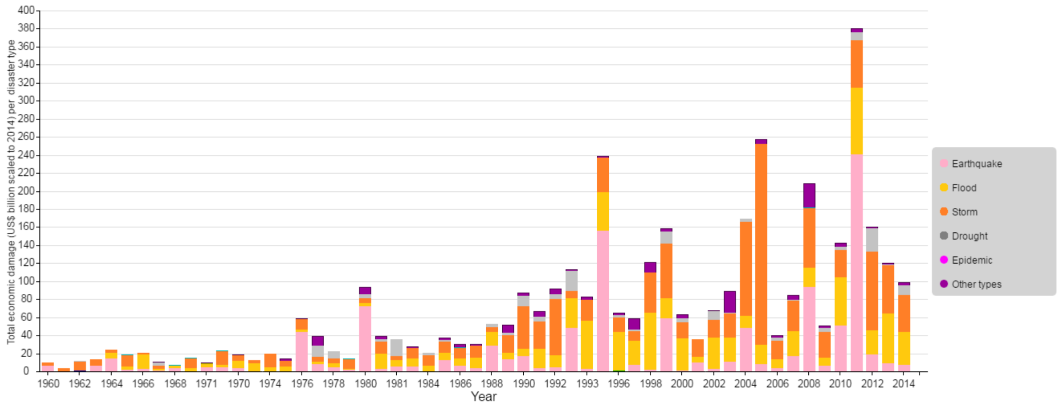

Figure 72 - Evolution of natural disasters global economic losses, 1960 – 2015 (Source: Centre for Research on the Epidemiology of Disasters (CRED) database, emdat.be/database)

In Europe, natural hazards represented approximately EUR 12 to 13 billion of losses per year and over 8000 casualties per year over the 1998 – 2009 period[245]. The hazards with the greatest impact are floods, which accounted for more than one third of the total losses. **In 2015, Europe represented 14% of the global losses, with EUR 11.4 billion**.

It can be noted that only 24% of the losses suffered in Europe during the 1998 - 2009 period were insured. An analysis by Munich Re on the impact of natural disasters shows that this fact is true globally; as, for instance, on the 10 costliest worldwide events over 1980 – 2015, 25% of the losses were insured[246]. This ratio varies from one year to another, and in recent years it tends to be closer to 30%, reaching 40% of the total EUR 83 billion global losses in 2015 (49% for Europe)[247]. In addition, though predictions remain uncertain, **climate scenarios by the**

[244] *Source: Emergency Events Database of Centre for Research on the Epidemiology of Disasters (CRED) - retrieved 06-05-2016*

[245] *Source: EEA publication, Mapping the impacts of natural hazards and technological accidents in Europe, 2011 ; Emergency Events Database of Centre for Research on the Epidemiology of Disasters (CRED) – retrieved 06-05-2016*

[246] *Source: Munich Re NatCat Service – 10 costliest events ordered by overall losses, march 2015*

[247] *Source: Swiss Re, Sigma n°1/2016. Note: The conversions from USD to EUR for 2015 data were performed at a rate of 0.902 (source: European Central Bank).*

European Environment Agency (EEA) tend to demonstrate that flooding events will increase in the coming years and decades.
Overall, these figures underline the growing impact of natural hazards on worldwide societies, and the increasing potential role to be played by the insurance sector in this growing market over the coming years. Satellites, by dint of their global coverage and large scale images, provide well fitted data for the monitoring of such events. This is true for both the anticipation of events (tracking the routes of hurricanes and storms, forecasting large heavy rain episodes for instance) and the post-event operations (delineating the damaged areas after a flood, spotting the pollution spills in the ocean, assessing the state of access and circulation means after an earthquake for instance).

Value chain characterization from an EO data usage standpoint

Current use of EO data

The link between a relatively recent and insightful domain such as EO and a more historical sector such as property insurance is not obvious at first sight. However, depending on the companies, up to 20% of the (re)insurers activity is directly related to the observation of the environment of the insured products, hence benefitting from synergies with EO. **Today the exploitation of satellite images by insurers can be segmented into 3 categories: risk modelling, loss assessment and index products**.

Catastrophe modelling *- Different approaches of EO by insurers, reflecting internal choices more than a competitive advantage*

Risk modelling (or catastrophe modelling) consists of building a probabilistic model on the likelihood of an event. Though natural disasters remain hard or impossible to predict, the reliability of the models impacts directly on the ability of the (re)insurer to forecast his future cash out-flows and therefore keep his solvability and profitability under control. Risk modelling is an upstream activity in the insurance value chain, which helps to calculate premium levels. It is traditionally exploited for claim-based products, but it is also valuable to price index products when no other source of information is available such as addressing a new market in a developing country for instance. This critical activity can be **managed internally,** especially in large (re)insurance companies, or through associations of professionals in the insurance sector such as the Oasis Loss Modelling Framework (UK), but can also be **outsourced to specialised companies** (such as the US global leader RMS).

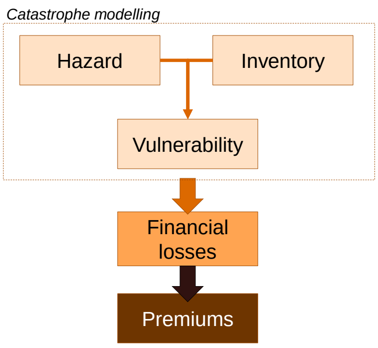

Figure 73 - Catastrophe modelling principle

Catastrophe modelling existed prior to the use of satellite data, and today (re)insurers continue to exploit different sources of information for their models, depending on the data: meteorological agencies provide weather history and forecasts, seismographic information is provided by geological agencies (such as the US Geological Survey – USGS) and wind information, useful for storms and hurricanes for instance, can be provided by entities such as the US National Oceanic and Atmospheric Administration (NOAA). **Strong discrepancies are witnessed between insurance companies regarding their sources of information**. For some of them EO is commonly used to build the models, representing the major source of data for this activity (for instance 70% of the data used by Willis Re is satellite data), while other companies do not exploit satellite images at all. Interestingly, some gaps can exist within the same company, as for AXA, where a risk modelling department has been using satellite images for a few years to validate and improve models, while another similar department still relies on "traditional" sources. This absence of a common trend between insurers (and sometimes within a given company) reflects the **perception of EO data as a complementary source**, which can be used, but which does not differentiate from other sources in terms of type of information, reliability or cost. Hence **the added value of switching to EO data or integrating EO data in the current processes is not clearly identified by some insurers**.

In addition to the type and reliability of information, a key aspect for risk modelling is the **long history of data**. The insurance sector traditionally exploits at least 10 to 15 years of data, and if possible brings this value up to 30 years. When EO is exploited, most common sources are Landsat satellites or Terra / Aqua (for the MODIS payload), and as of 2016, younger systems such as the Sentinels are immediately disadvantaged.

Loss assessment *- EO cannot replace field experts, but serves as a complementary source to support existing processes*

Loss assessment (or damage assessment) is part of the core activity of insurers, as a key step in the classical claim-based scheme. It consists in comparing the claims received from the clients with the actual material damages that occurred on the field, in order to define the amount of indemnities to be paid by the insurer to its client. The benefits of EO on this process can be of two types: in anticipation of the event, and for claims handling process after the event.

Insurers' vision on the coming natural hazards allow them to both improve their service quality and reduce the material losses. With the right information prior to an event, the **clients can be warned** and given instructions to protect their belongings and remove sensitive and costly objects. Besides the reduced indemnities for the insurer, these initiatives have a strong impact on relationships between both parties. A forecasted catastrophe also allows **adjusting the sizing of the call centres** to receive and handle the customers' calls after the event, and **requesting field experts** to be able to cover the affected area (this is performed by 3rd party entities and often constitutes a bottleneck of resources). In this process, EO data represents an appropriate source with a global coverage. However, traditional sources (meteorological, geological and atmospheric agencies) which have been used for decades remain available, and satellite images represent a complementary tool rather than an exclusive approach. The added value of EO is in the quality of the forecasts but is **hardly measurable** as a contributing source among others, resulting in a cost sensitive attitude from insurers. The open and reliable data of Copernicus makes it a good candidate as a source, but the volume of this type of EO based activity remains too low to quantify a potential contribution.

After an event, the added value of satellite images is more clearly identifiable as a mean to assess the damages remotely, and to reduce the costs associated to the commissioning of experts on the field. This cost reduction can be achieved by avoiding some of the field verifications, or by optimising the interventions of the experts.

The **replacement of field observations** by satellite images raises **technical limitations for EO data**. Assessment of insured goods is not a binary science and in some cases the evaluation requires close-up observations. In other cases, damages are just not observable from the sky, such as inside a building for instance. The use of satellite images can, therefore, completely replace field experts in a limited number of cases, **for which the damages are obvious and do not require more advanced verification;** for example, on large scales damages such as flooded or burnt areas. In addition, satellite images can also be exploited to dismiss claims when the area is obviously not affected, **reducing the verification costs associated with fraudulent claims**.

When physical verification cannot be avoided, the **optimisation of the field interventions** relies the ability to have a global view of the event, with also low requirements on the resolution of the images. However, if insurers do not have the critical requirement to have the images in the few hours following the catastrophe as emergency services do, **it remains important in some cases to have the images quickly available (one day or two)** to have a vision of the situation before it evolves too much. This implies either a high revisit frequency or the ability to orient a satellite on an area of interest, which involves commercial EO satellites.

In fact, the commissioning of experts remains the standard and common procedure, for **EO data technical limitations only allow improvements of the existing methods**. Depending on the hazard type and size, insurers can choose to use a cost efficient (low resolution, low responsiveness) source of data, or a costlier source (commercial satellites) when the information is more valuable. In both cases, satellite images are not the only source exploited and are combined with the other information sources available.

Index products *- New markets addressable by EO-enabled products, high potential in emerging countries*

Index products are a more recent offer from insurers, enabled by the use of EO data. Based on a continuous monitoring rather than an intermittent assessment, they are particularly adapted to agricultural activities with erratic cycles (fodder for instance) and to livestock insurance. The principle is to exploit satellite images to measure observable and quantifiable parameters and to compute an index from these parameters. This index typically represents the vegetation biomass, and indemnities are paid when the biomass is estimated below a defined level (threshold). It can be noted that the aim is not to measure the risks or impacts of precise natural events, but rather to measure the final consequence on the biomass. Thus index products can be sold by insurers as a **protection against various natural disasters, in particular drought, frost, excessive rains and floods**.

The **correlation between the index value and the reality of the field** represents the technical challenge of these products regarding the exploitation of raw EO data. Insurers, as non EO experts, rely on **3rd party companies and other partners** (research institutes and universities) to provide these indices.

Index products, with the absence of field operations during the exploitation, open **new markets in remote areas**, especially in emerging countries, where traditional claim based schemes are not economically viable. This is for instance the case for pastoralists in Kenya and Ethiopia who can insure their herds against droughts.

The applications for index products imply 3 main characteristics for the EO data:

- Fodder fields and clients for livestock insurance are spread across wide regions. Satellite images require **low to medium resolution**, with pixel width varying from 20 metres for the highest resolutions up to a couple of hundred metres.
- A critical aspect for index products is the ability to monitor the full area of interest regularly in order to compute the index at a sufficient frequency. Uncertainty about cloud coverage (for optical images) requires the satellite to make several scans of the same area before being able to have a complete picture. Hence a **high revisit frequency and a large swath** are key parameters. Typical frequency for index computation is between 2 to 3 weeks.
- Finally, a strong requirement for these products is the **depth of data history**. Similar to risk modelling, the correlation between the available data and the interpretation of the reality is directly impacted by the amount of past data available to build the models. **Insurers usually expect to have over 10 to 15 years of data**, leading to the choice of EO sources with a long operating history such as Landsat or MODIS.

For these applications, the Sentinels provide well adapted payloads, and the history of data stands as the only remaining barrier to increasing the use of Copernicus by insurers for index products.

Table 33 - Overview of main EO applications for the insurance sector (source: PwC-STRATEGY& analysis)

Application	Added value of EO	Use of EO	Use of Copernicus	Potential of Copernicus
Risk modelling	Moderate	Common	Punctual	Good
Loss assessment	Moderate	Limited	Punctual	Moderate
Index products	High	High	None	High

The figure below sums up the contributions of EO to the different activities of (re)insurers and the associated benefits.

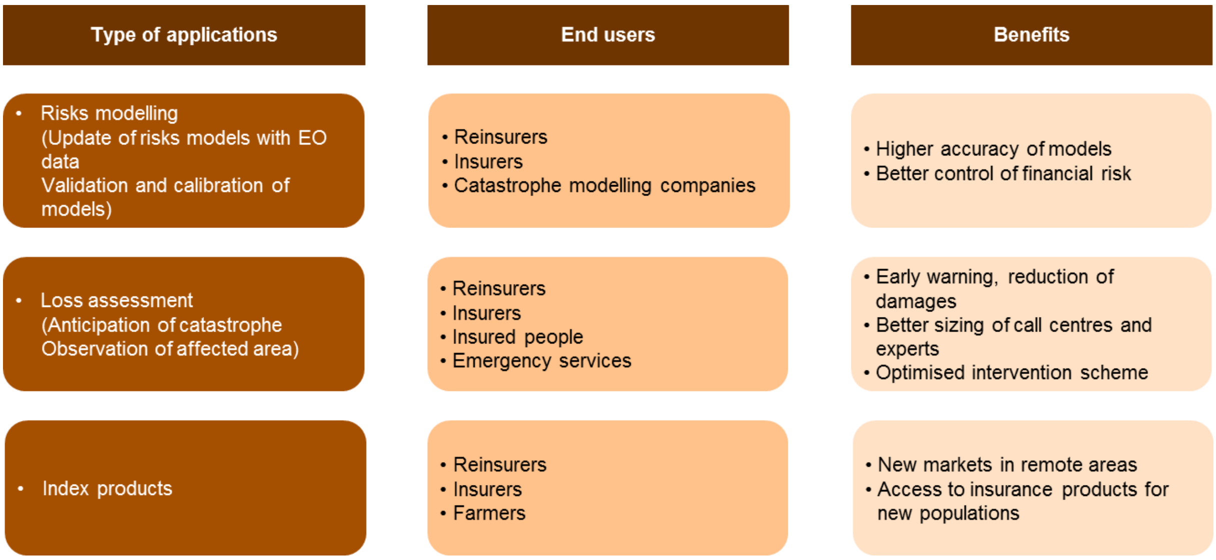

Figure 74 - Overview of EO contributions to the insurance sector

Market structure and trends

The insurance market is a **fragmented and very mature market**, composed of both very large insurers and reinsurers (Munich Re, Swiss Re, Willis Re, AXA…) and smaller companies. For the largest part of the insurers' activities, EO impacts existing products and markets, providing **costs reductions and improved quality**. Regarding parametric products EO acts as an **enabler for a new** (less than a decade of history) **yet promising market**.

Key Drivers	Key Obstacles
⬀ EO opens opportunities for new (re)insurance policies with **high applications potential in developing countries**, increasing the customer base.	⬂ Other **sources of data already exist** for risk models and damages assessment, which have proven to be efficient. Switching to new data sources such as EO requires new knowledge.
⬀ Potential for **costs saving approaches** and **improvement of the level of customer service** for loss assessment processes.	⬂ Insurance related to meteorological hazards relies on **long data history**, changing source implies data continuity issues.

⬀ **Open data policy fosters** the adoption of EO products and applications in a context of limited added value over other existing data sources.	⬂ Some insurance applications require **high technical expertise** in EO data, which can create scepticism in a rather conservative sector. ⬂ Insurers are not EO experts, and can be reluctant to use EO when access to data and the **interface to manipulate it are not adapted** to their needs and require some expertise.

Table 34 - Synthesis of main key drivers and obstacles related to Insurance (Source: PwC-Strategy& analysis)

Main players (examples) globally and in Europe

The principle of risk handling implies traditionally large insurance companies addressing global markets, with billions of US dollars worth of premiums. World leaders such as Berkshire Hathaway (US), Allianz (DE) or AXA (FR) each generate in excess of USD 100 billion worth of revenues[248]. This is also true on the reinsurance market where leaders such as Munich Re (GB) accounted for over USD 65 billion of Net Written Premiums (NWP) in 2014, and companies such as Markel Corp (US), with NWP of nearly USD 4 billion in 2014, are considered as "small" players[249].

Large companies are more likely to be involved in EO activities as the investment is more easily bearable (data acquisition, staff training, products development etc.). Among the reinsurance companies involved in this study, **Swiss Re** (CH) is one of the world largest players, with over USD 35 billion of income in 2015. They exploit EO for risk modelling, loss assessment, crops monitoring along the season and they developed index products for the European market (less than 2% of their revenues) and for emerging countries such as India (where it represents 80% of their activity). They own in-house capabilities to download, manipulate and merge sources of EO data such as Landsat, MODIS and SPOT (Copernicus is not used due to the data continuity issue). **Willis Re** (GB) is a reinsurance broker (about USD 4 billion of revenues in 2014) which also owns capabilities to handle EO data, including Copernicus for punctual loss assessment. They build insurance-tailored products that can be can exploited internally but also provide services to their customers (insurers), such as risk model calibration and validation.

Regarding insurers, **AXA** (FR) exploits EO data for similar activities, although they tend to use EO more as a complementary source to consolidate their traditional practices and sources. Regarding index products, strong discrepancies are witnessed between insurance companies in terms of maturity. **Allianz** (DE) has offered parametric products since the end of the 2000s while **Groupama** (FR) just launched its first index products in 2016. In Spain, **Agroseguro** (ES) is in charge of the management of the agricultural insurance at national level, on behalf of 23 insurance companies. They developed and have provided index insurance policies since the early 2000s (more detailed information is provided below in the case study).

To turn satellite images into insurance products, **VAS companies** are key players in the value chain for the (re)insurers who do not own in-house capabilities or expertise. Catastrophe models and derived products tailored for the insurance sector can be provided by dedicated players such as **Risk Management Solution RMS** (US), which delivers models and data for natural hazards (cyclones, earthquakes, floods, storms, tsunamis etc.) and others (cyber risks, terrorism, life risks). Among the interviewed actors, **Oasis Loss Modelling Framework** (UK) is a non-profit association of over 50 (re)insurance companies, which aims to foster the development of the catastrophe modelling community's knowledge and environment. **Deltares** (NL) is an institute for applied research in the field of water and subsurface, which provide insurers with forecast models for water related hazards such as floods. These models are used as inputs by insurers, which translate these inputs into potential economic losses for their clients.
Airbus Defence & Space (FR) is an example of player which is involved as EO expert. Their knowledge and know-how on satellite data makes them central players for the elaboration of index products. Universities can also provide EO and technical expertise, and the **University of Valladolid** (ES) for instance is the partner of **Agroseguro** (ES), providing the index computation from the satellite images.

Data flow along the value chain

[248] *Source: Annual reports of main insurance companies*
[249] *Source: Fitch Ratings, Global Reinsurance Guide 2015. Note that these figure include both life and non-life insurance.*

The parameters considered along the EO value chain in the insurance sector are summarised in the figure below, from the acquisition of EO data to the impact on the (re)insurers business and competitiveness.

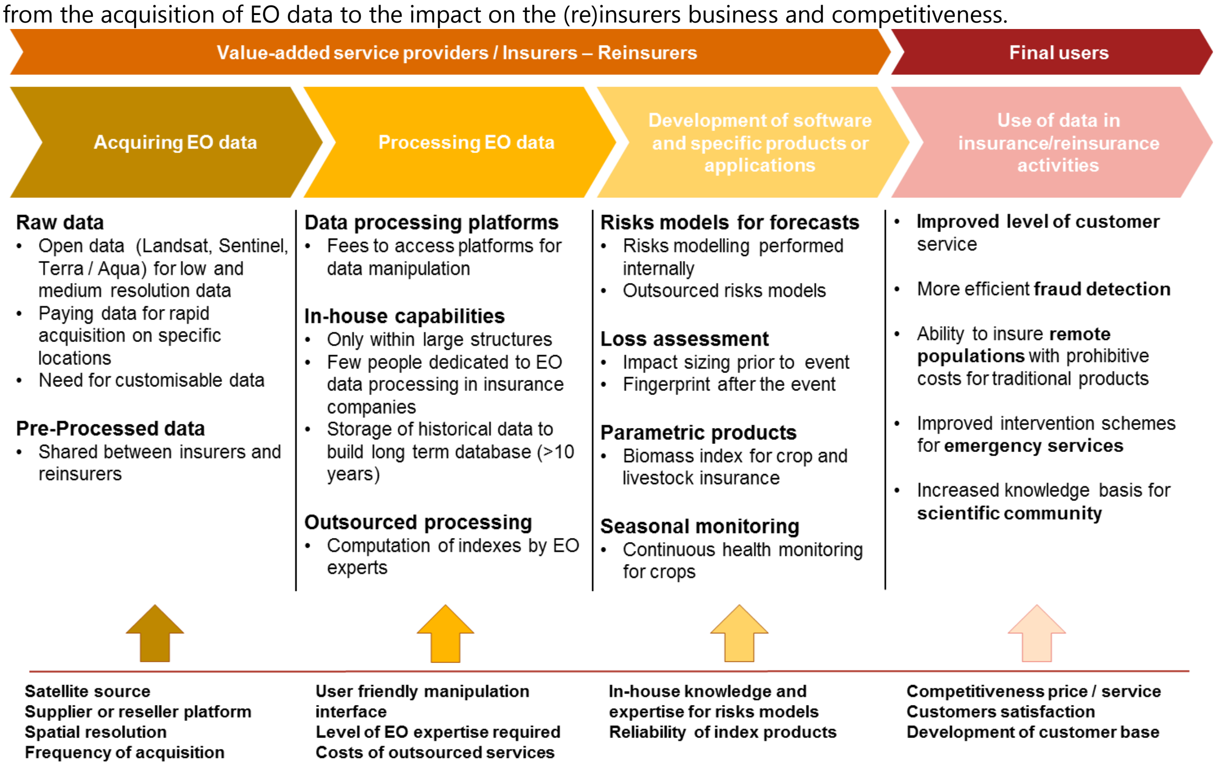

Figure 75 - EO data value chain in the insurance sector (source: PwC-STRATEGY& analysis)

Data collection and processing platforms

The type of data required by (re)insurers varies considerably depending on the type of application.

As of 2016, **index products** are mostly built on data from **Landsat, Terra and Aqua** satellites (Terra and Aqua are equipped with the **MODIS** payload). These sources are mixed together as Landsat 8 offers a good resolution at 30 metres per pixel but a low revisit frequency, at about 2 weeks; while MODIS data has a lower resolution (250 metres per pixel) but offers a high revisit frequency of 1 to 2 days. The **Sentinels are well adapted** with a good resolution (20 metres), sufficient revisit frequency (5 to 6 days), and a radar instrument (not possible with Landsat and MODIS), but **they face the lack of data history** with just 1 year available. It can be noted that although Sentinels deliver free to access data and index computation is a recurrent task (every 2 to 3 weeks), index products brought to market by VAS companies are priced on the service provided rather than the costs of images. Thus the open source aspect remains an advantage but should not be perceived as a strategic differentiation with regards to commercial sources.

The issue with data history for **risk modelling** also applies to loss assessment. However, the continuity of data is less critical in this case, and other commercial sources can be used. Willis Re for instance exploits data from the **Worldviews** and **Quickbird** satellites of DigitalGlobe (in addition to Landsat and MODIS). They acquire data both from the image providers' platforms and through the **S3 platform** of Amazon Web Services.

In the case of **loss assessment**, history of data is not a barrier. However, the added value of EO relies on the short delay between the event and the availability of images. A key asset of some commercial satellites is the manoeuvrability, which allows orienting the payload on the area of interest. Furthermore, damages assessment requires a higher resolution to be an actual alternative to field commissioning of insurance engineers. As a consequence, **SPOT and Pléiades** are the most common sources for such applications, delivering sub-metric resolution images with a high reactivity.

The recent trend from **EO 2.0 actors** to deploy large constellations of EO satellites, providing near real-time data, appears to be an opportunity to improve the responsiveness of satellite images. Insurers could benefit from these new business models which should provide **low cost EO data at high to very high resolution** for **loss assessment applications**. It can be noted that current EO satellites such as Landsat, Copernicus or MODIS will remain more adapted to other applications such as catastrophe modelling and index products as it involves data continuity and reliability issues.

Outsourced and in-house EO capabilities

Intermediate users such as VAS companies, geo-information companies and EO experts remain **central actors in the delivery of EO based products** exploitable by (re)insurers as today a **small share of (re)insurance companies have the knowledge and in-house infrastructure to handle and customise satellite data** (mostly large structures, and mostly reinsurers as their activity is more centred on natural disaster than traditional insurers). Switching from "traditional" sources to satellite data implies a change in internal practices, new knowledge acquisition and requires training. Today insurers often ignore how to get this training, and who to contact to have more information. This leads to **a reluctance in doing the effort** as the specific added value is not easily graspable and the current processes are considered satisfactory.

The progressive increase in the use of EO data will naturally lead to a development of internal knowledge and expertise by (re)insurers. This will have an impact mostly in large structures, more willing to invest in data, infrastructure and trainings. However, (re)insurers do not expect satellite data to become a stand-alone source and as of 2016 other sources of data are forecasted to remain widely used. The development of internal expertise is therefore expected to be limited. The development of EO capabilities customised for insurance activities should be more common within **catastrophe modelling companies, which are able to combine the VAS expertise and the (re)insurers' products**. Communities of (re)insurers can share and mutualise their expertise and practices related to EO, such as the Oasis Loss Modelling Framework not-for-profit company which is centred on catastrophe risk modelling.

The adoption of EO by (re)insurers should have a greater impact on the intermediate users, and the overall satellite-based EO market for insurance is forecasted to grow at a CAGR of 17.5% over 2015 – 2020 by Technavio[250], reaching about USD 88 million (EUR 79 million) for Europe in 2020. This underlines the key position of intermediate users and EO companies for the (re)insurers, which strongly rely on them to provide processed data and information. Beyond the EO intermediate users, (re)insurers also exploit Geographic Information Services (GIS) products, which add a layer of information by combining the satellite data with other sources such as in-situ, navigation or social data. However, the geographical information required by (re)insurers is rather specific such as the geographical implantation of their clients and the vulnerability maps. This information is retained internally and its manipulation cannot be outsourced, mitigating the gap in added value between EO actors and GIS actors (the overall GIS data and services markets in Europe are forecasted by Technavio to grow about 9% per year until 2020[251]).

It can be noted that in terms of economic impacts, though intermediate users should experience a high growth rate in the coming years, the overall impact of EO will remain predominantly generated by the end-users as the natural disasters insurance market in Europe is much larger than the associated EO market (with a ratio of nearly 10).

Development of value-added software, products and applications

(Re)insurers are not EO experts and their internal activities do not aim at creating dedicated software and tools. It is important to note that EO data, no matter its quality, resolution or accessibility, constitute an input for (re)insurers whose core activity and knowledge remain to turn available information into insurance policies. Therefore, they tend to either use existing interfaces which easily fit their need or buy the final product from external suppliers, EO experts. To illustrate this aspect on risk modelling for instance, **their core activity remains the hazard and vulnerability assessment** which exploits processed EO data as an input **rather than turning the EO images into input data**.

In the recent years, some insurers and reinsurers started to exploit EO data for **risk model comparison and assessment**. The principle is to **validate and calibrate risk models** with regards to the reality of the losses undergone, improving the reliability of such models. This service is performed internally by players with in-house capabilities and knowledge, such as AXA for instance. Willis Re goes further and exploits its internal capabilities to provide this service to its clients (insurance companies).

Regarding loss assessment, typical products include **delineation maps after floods, vulnerability maps for landslides and coastal erosion, or analysis of burnt areas** (fire departures, propagation, and new potential starts). These products can be created by using existing platforms and APIs, but as detailed previously in this report there is not many specific applications for insurers and the added value for their business remains limited.

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[250] *Source: Technavio, Global Satellite-based Earth Observation market, 2016-2020*
[251] *Source: Technavio, Global GIS market, 2016-2020*

The creation of parametric products, through a “map” of the **bio mass indexes values**, represents the opposite case, with **very specific needs from insurers**. The indexes are built according to each insurer requirement and specifications, and no standard or universal method exists. **The challenge is to transform an optical (or radar) image into a numerical index**, which has to be correlated as much as possible with the reality of the field. **Dozens of parameters have to be taken into account** to reach an automated process, such as the colours of the image, the nature of the ground, the rate of clouds, the level of soil moisture, the level of air humidity or the presence of shadows to name few. As a consequence, these products are developed in close collaboration between (re)insurers and **EO experts, who retain the required experience** and analysis capabilities, such as **VAS companies** like Airbus D&S or **universities**.

End users

When comparing the approach adopted on the (re)insurance value chain with the other value chains addressed in this handbook, it is important to note that the benefits, barriers and practices discussed in this chapter are mostly centred on the end users, that is to say the insurance and reinsurance companies, rather than the intermediate users which constitute the EO downstream market (VAS companies and other EO related actors).
The economic benefits, detailed in the next chapter, reflect this situation with most of the revenues enabled by Copernicus coming from the (re)insurer’s activity rather than from the EO services market. Indeed, with billions of euros of damages each year in Europe (and dozens of billions at a global scale), the impact of Copernicus on the natural disasters insurance market is likely to be much more than in the EO services market, and the contributions from Copernicus can generate a considerable impact.

Beside the (re)insurance companies, other actors can benefit from Copernicus, who can be included in a wider vision of the beneficiaries of the insurance products. It includes the individuals and businesses who underwrote property insurance policies for natural disasters, farmers benefiting from index insurance products, and institutional services for emergencies and civil protection.

Individuals and businesses covered by natural disaster insurance benefit from EO exploitation through the improvement of disasters forecasts (when it is possible):

- It allows a **reduction of the losses** by the early warning of their insurers. Regardless of the method (nowadays text messages is a widespread mean), the clients can take appropriate measures (protection of the goods, removing of sensitive objects etc.).
- It improves the **level of customer service** by the insurer, meaning the calls can be handled more promptly, the required field verifications by experts are better organised and eventually the indemnities are received in a short period of time.

The benefits for **farmers insured by index products** are directly linked to the access to new, innovative products.

- In Europe (and in developed countries in general) this remains mainly applied to fodder yields, and the main benefit is the ability to have an insurance policy for this type of activity. This was not the case before as this production has erratic cycles, and is much harder to monitor and assess than regular crops such as corn and wheat.
- In developing countries, farmers often suffer from hostile environmental conditions (drought is a widespread threat in Africa for instance). Livestock insurance is too expensive with traditional insurance schemes (prohibitive cost of field commissioning, lack of infrastructure), and the ability for farmers to insure their herds is a new approach, releasing the constant financial tension they used to undergo and fostering future prosperity.

Besides insurance products, satellite images of catastrophes also strongly benefit public entities, especially **civil protection teams and emergency services**. They can have access to large scale data and can improve their understanding of the situation, their intervention schemes for rescue commissioning and reduce both the casualties and material damages.

Current role of Copernicus

As of 2016, the data provided by Copernicus does not enable new products or markets for insurers, but is rather complementary to other satellites and non-satellites sources. Copernicus contributes to risk modelling and claim based products, but the **data continuity issue prevents, as of 2016, its exploitation for index products**.

For **catastrophe modelling activities**, the absence of history can be a weakness for the statistical analysis of events. However, EO also contributes on different means to catastrophe modelling, on which Copernicus has a higher potential for growth in the short term. In the pre-event phase, the vulnerability assessment of (re)insurers’ clients requires **reliable data**, as delivered by Copernicus, to analyse parameters such as coastal erosion and past floods or landslide scenes. The **standard and easily customisable** format also supports an automation of the process. After an event, in the post-event learning phase, which consists in comparing the model forecasts and the actual events, the reliability of Copernicus data is a key consideration for the models calibration, validation and evolution. Beside these regular opportunities for exploitation of Copernicus, catastrophe modelling can also be helpful when addressing new markets on which few information is available, for instance for the initial pricing of index products. Finally, some of the catastrophe modelling companies involved also identified promising sectors such as forestry management, where the risks modelling could be more widely exploited, increasing the contribution of satellites images. It should be noted as numerous other sources of data are used by insurers, **the total contribution of Copernicus satellites data remains relatively low, being estimated below 3%**.

For loss assessment activities, Copernicus images are used for **event anticipation** by monitoring the routes of storms and hurricanes for instance. After the event, Sentinels data can be used to **assess the extent of the damages**, **and Sentinel 1A's radar capability offers a strong advantage in obtaining an image of the situation in cloudy conditions** as it can be in the case of storms and heavy rains. The large swath is also an asset to have a global view of the scene and counter the lower revisit frequency. This was the case in 2014 for floods in the Sava river basin, or in 2016 for floods in France and as well for the large fires in Fort McMurray region in Canada. The images can be exploited to create **delineation maps** which can be exploited by (re)insurers to facilitate the commissioning of their experts. The commissioning of experts is most of the time necessary to provide accurate vision of the reality of the losses, but in the cases of large and obvious damages, directly observable on satellite images, this field observation step can be avoided, ensuring costs and time savings. The satellite images can also be exploited for particular cases of **fraud**, when the claims received can be invalidated through a visual analysis of the scene and of the neighbourhood. As for risk modelling activities, Copernicus remains a complementary source of information and (re)insurers involved in this study evaluate that its contribution does not exceed 3% of the overall activity.

It appears that beyond being simply a complementary source of data, as legitimate as traditional and other satellites sources, Copernicus offers intrinsic assets for (re)insurers such as its **data reliability, standardised format, radar capability and large scale images**, and of course its **open data policy**. The current use remains very limited, and **a wider adoption of the Sentinels data could be fostered by facilitating the switch of internal practices from one type of data towards Copernicus data**. This implies some training for catastrophe modelling companies or departments, to become familiar with the platform principle, the elementary processes of data acquisition, and technical know-how for data manipulation and customisation. Indeed, several stakeholders in the (re)insurance value chain tended to stick to their traditional practices due to a lack of support on the basic first steps and were addressing these issues in a handmade approach. The adoption of satellite images is therefore more dependent on personal interest and involvement of the people dealing with catastrophe modelling topics rather than stimulated and guided by knowledgeable external actors.

Among the core services of Copernicus, the **Copernicus Emergency Management Service (CEMS) – Mapping** provides 2 types of on-demand services, for fast provision after an event and for activities not related to immediate response[252]. These services provide geospatial information derived from satellite data (and completed by other sources, such as in situ data) to actors involved in the management of natural disasters emergency situations. They are exploited during all the phases of the emergency cycle, are free of charge, but only authorised users can activate the service: participating states in the European Civil Protection Mechanism, the Commission Directorates-General, EU Agencies, the European External Action Service and Humanitarian Aid Organisations.

The **Rapid Mapping** service provides 3 types of standardised maps within hours up to 5 days after an emergency event. **Reference maps** are based on pre-event images and provide knowledge about the territory and the exposed assets. **Delineation maps** show the extent of the event and its evolution with time, by delineating the affected areas. **Grading maps** reveal the magnitude of damages in the area (for instance the number of buildings destroyed after an earthquake).

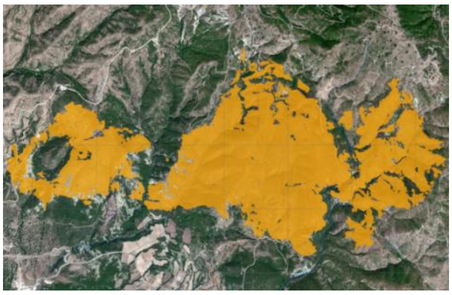

Figure 76 - Example of a fire delineation map in Greece, source: European Union

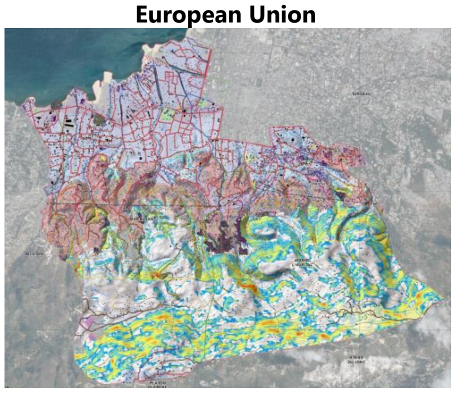

Figure 77 - Example of a post-disaster situation map in Haiti, source: European Union

[252] *Source: http://emergency.copernicus.eu/mapping/copernicus-emergenc 15/07/16)*

The **Risk and Recovery Mapping** service applies to prevention, preparedness, risk reduction and recovery activities. Beside reference maps, it delivers **pre-disaster situation maps** which provide up-to-date thematic information to support contingencies measures on vulnerable areas in order to minimise the potential losses. **Post-disaster situation maps** provide thematic information to support reconstruction and mapping of long term impacts. They may need to be updated regularly to monitor the evolution in time.

Table 35 - Products delivered in the frame of the Copernicus Emergency Management Service (CEMS) (source: CEMS website)

Service	Products	Use
Rapid Mapping	Reference map Delineation map Grading map	**Authorised users only***
Risk and recovering mapping	Reference map Pre-disaster situation map Post-disaster situation map	

** Authorised users include participating states in the European Civil Protection Mechanism, the Commission Directorates-General, EU Agencies, the European External Action Service and Humanitarian Aid Organisations*

Regarding the management of floods events, a dedicated service operational since 2012, the **European Flood Awareness System (EFAS)** has been set up in the frame of the CEMS, in collaboration with the national hydrological and meteorological services of member states to support the anticipation (up to 10 days in advance) and real time operations and decisions. It relies on the diffusion of warning emails, with 3 levels of notification (formal flood notification, informal flood notification and flash flood notification)[253]. These notifications however are just a call for attention to the EFAS partners, who then can find more information on the coming events, and take appropriate measures.

The CEMS is not exploited by (re)insurers as they are not authorised users, for they are not actors of the civil protection or emergency rescue services. In addition, (re)insurers' needs tend to be more specific, with different constraints. For instance, though delineation maps are common products to both parties, (re)insurers will not demand the same responsiveness of few hours to get the map, and this information needs to be crossed with the geographical distribution of their clients.

Copernicus socio-economic impact assessment

Copernicus enabled revenues

As of 2016, the economic benefits for the Insurance sector (including both EO/GIS companies and (re)insurers) which can be attributed to Copernicus remain very low, due to both its limited use as a data source and the moderate added value of EO in general over other data sources. In the coming years the use of Sentinels data should increase their economic impacts for (re)insurers:

- **Risk modelling** is currently **the only application exploiting Copernicus** data in a noticeable proportion of the total, **accounting for up to 30% of the data** for some reinsurers (Landsat and MODIS remain the most common sources). It is difficult to measure the economic benefits generated by the Sentinels data as it only constitutes one of the inputs to the (re)insurers' models, and no quantification exists of an average contribution of the different inputs to the reliability of the models across the insurance market (other inputs include other EO data, meteorological data, winds and atmosphere data, precipitation measurements etc.). In addition, the risk model itself is an input to the pricing strategy of insurers, which defines the final economic impact. However, risk modelling remains an essential activity and satellite images are a more and more common source of inputs. Copernicus' share should increase as long as its data history grows.
- **Loss assessment**, by exploiting EO data, does not represent a field of high exploitation for Copernicus, as responsiveness and high resolution requirements tend to foster the use of commercial satellites.
- **Index products** represent a minor part of insurers business, but are expected to grow in the coming years, especially on emerging countries markets. This activity fully relies on EO, but Copernicus, despite its well-fitted capabilities, is not used as of 2016 due to the requirement to have a data set with a long history. This barrier should disappear in the future, and it constitutes the **main opportunity for growth and revenues for Copernicus**.

[253] *Source: JRC, The European Flood Awareness System – Status and development, 2015 Annual report*

Table 36 - Copernicus enabled revenues for the insurance sector (source: PwC–STRATEGY& analysis)

Application	Type of benefit	Potential of economic impact	Added value of EO	of which, added value of Copernicus	Expected evolution of Copernicus impact
Risks modelling	Lower financial risk	Moderate	Moderate	Low	Slightly positive
Loss assessment	Costs savings	High	Moderate	Low	None
Index products	New market	Moderate	High	None	Very positive

As detailed below, the total economic benefits attributable to Copernicus aggregate the benefits for the GIS downstream market (intermediate users) and for the (re)insurers (end-users). Regarding the end-users' benefits, the quantification of the impacts from Copernicus in monetary terms remains a delicate exercise for 3 reasons:

- The activities of catastrophe modelling do not represent sources of revenues but **operational costs** for (re)insurers. The economic benefits derived from it (as a reduced financial risk) rely on the assumption that **they are directly related to the total amount of losses insured**. Note that for loss assessment, though it is also a cost for (re)insurers, the benefits from EO are costs reductions, which are more directly identifiable.
- The contribution of EO in general to the economic benefits is **hard to distinguish from the other sources of information**, and the few (re)insurers interviewed which could provide broad figures did it from the data share perspective rather than the economic point of view. The exercise involves even more uncertainty when focusing on the weight of Copernicus only.
- **Strong discrepancies** have been identified within the (re)insurance sector regarding the practices on EO. It is therefore a simplistic approach to extrapolate the data gathered through the interviews conducted to the rest of the market.

Keeping in mind these notions and hence taking cautions with the direct interpretation of the final figures, a broad estimate can be calculated for the **total potential economic impacts of Copernicus on the European insurance sector, representing between EUR 2.6 million and EUR 171 million in 2015**. It is important to note that a major part of these benefits is generated by the end-users' activities (the benefits for the GIS market are estimated below EUR 3.3 million). Indeed, despite the low penetration of Copernicus data in the end-users activities, the very large amounts at stake in natural disasters insurance mechanically lead to substantial benefits.

The lowest values include only estimates of revenues identified through the direct discussions with the stakeholders. The highest estimates are the "highest" (optimistic) extrapolation of Copernicus impact for the (re)insurance market and the GIS market (VAS and data sales). Note that in both cases, index products' benefits from Copernicus did not exist in 2015.

Table 37 - Copernicus broad estimates of economic benefits for insurance sector in 2015 (source: PwC-STRATEGY& analysis)

M EUROS	Insured losses	Enabled revenues for the downstream sector (GIS market)	Enabled revenues for the end users ((re)insurance market)	Total
2015	5600	0 to 3.3	2.6 to 168	2.6 - 171

Non-monetary benefits of Copernicus

The benefits of Copernicus go beyond the purely economic frame as some of its applications are related to the **management of natural disasters**. This represents a vital **strategic activity for governments** and civil protection entities as a mean to protect citizen lives. **Sentinels' large swath** provides a global view of events, supporting the intervention schemes of emergency teams and providing a full picture after an event. The **Sentinels radar capability** is also an asset for monitoring natural disasters as some of them are directly implying high cloud coverage (storms, floods and excessive rains). The **delineation maps** produced support the emergency services and local authorities, and in this context the Copernicus **reliable and verified data** is an asset. Though commercial sources are often selected for their high responsiveness, Copernicus also provides images, especially for large scale events. In Europe the Copernicus Emergency Management Service (CEMS) exploits the Sentinels and Copernicus contributing missions to provide these maps.

More generally, **statistical analysis (and forecasts) of natural disasters** for hazard monitoring and risks assessment provides a solid database to observe and understand the **evolutions of our climate**. If resulting skyrocketing economic impacts might be the first concern for the insurance sector, global **scientific knowledge and political awareness** will also benefit from these inputs. EO is a prevalent source of data for this, and though

Copernicus may not offer a differentiation advantage for this approach, it is an additional, reliable and free to access source of information completing the existing sources.

In the future, Copernicus should be exploited to build parametric products. The open data concept will give access, through the enabling of viable business models for insurers, to **insurance products for precarious populations**. Current examples of pastoralists in Kenya and Ethiopia which can insure their herds, their main and only source for living, highlight how these populations can change their fragile situation and start growing perspectives. Here the reliability of Copernicus data and its large regions coverage are also assets to answer insurance products requirements.

Copernicus projected contribution to the global and European socio-economic impacts

The current impact of Copernicus on the European insurance sector remains limited for two main reasons.

- Some insurance applications require **specific satellite capabilities which are not in the scope of Copernicus** (high resolution, steerable satellites for instance), therefore with **no forecasted evolution**. Indeed, on this aspect some commercial satellites with better fitted capabilities will remain more adapted for some specific uses (loss assessment more particularly).

- Other applications, especially the development of **index products**, do not exploit Copernicus because of the **young age of the constellation**. However, the data required for these applications fit well with Sentinels capabilities, and the barrier will naturally fade away in the coming years. **A progressive increase in the use of Copernicus can be expected** on this aspect, as many insurers and reinsurers already expressed their interest in the type of data delivered by the Sentinels. However, it is important to note that the insurance parametric products developed, as a new market, account for a small share of insurance revenues in Europe (though no consolidated figure exists, below 5% seems a realistic assumption). This market is expected to grow in emerging countries where agriculture is subject to hostile natural conditions with limited financial protection. India, Ethiopia and Kenya are examples of countries where this market has recently developed, representing more than 80% of some insurers' revenues in some cases.

In terms of time horizon, though no fixed and precise history depth is required to be able to develop index products (the deeper the history the higher the reliability of the product), (re)insurers traditionally expect to have at least 10 years of past data set available, and usually work with 15 to 20 years of history. **In these conditions Copernicus' first contributions to the index products market can be expected to arrive around 2025.**
In parallel it can be considered that along the coming years, the better experience of (re)insurers with these products should help in reducing the minimum history required, anticipating the rising of benefits of Copernicus. However, in the meantime (re)insurers developing index products rely on already available sources (MODIS and Landsat typically) and the use of Copernicus data will imply changing the data source, with technical issues regarding the reliability continuity of the index and of course the laborious rework of 10 years of satellite images. This offset in Copernicus availability creates a barrier to enter the market and therefore it seems unrealistic to expect sizable benefits earlier than 2025.
A means to shorten this access to market is identified by various stakeholders, by reconstructing the history "artificially". The past data set of available sources is calibrated on Copernicus data to ensure continuity, generating as much history as possible with other satellites. This operation however implies a considerable amount of rework, and should be achieved quickly to ensure its availability before the history of Copernicus becomes "naturally" available.

From an economic perspective, the principle of parametric insurance is much more attractive than the traditional business model, and (re)insurers have many reasons to support its development. The current main barriers to the expansion of such products are the technical knowledge to build them and the ability to connect this knowledge to the insurers' specific needs.
Under the same precautions as presented above in the section "Copernicus enabled revenues", a projection of the economic benefits of Copernicus for the insurance sector can be broadly estimated.

Table 38 - Estimations of the current and prospective economic benefits from Copernicus for the (re)insurance sector (source: PwC-STRATEGY& analysis)

(M EUROS)	Insured losses in Europe	Enabled revenues for the downstream sector (GIS market)	Enabled revenues for the end users ((re)insurance market)	...of which impact on index products	Total
2015	6200 (10 years average)	0 – 3.3	2.9 - 186	0	2.9 - 189
2020	7039 (10 years average)	0.1 – 43	3.25 - 211	0	3.35 – 254

The forecasts for the insured losses undergone in 2020 assumes a constant increase of the 10-years average between 1980 - 2015 and 2015 – 2020. It can be noted that the difference with the 2015 values presented previously (Copernicus enabled revenues) is due to the fact that to be able to provide a more meaningful evolution of Copernicus contribution the insured losses value used is a 10 years average, which is higher than 2015 value.
Regarding the index products market, the share attributed to Copernicus remains 0 in 2020 as only 6 years of history will be available. An estimate is provided for 2025 in the case study.

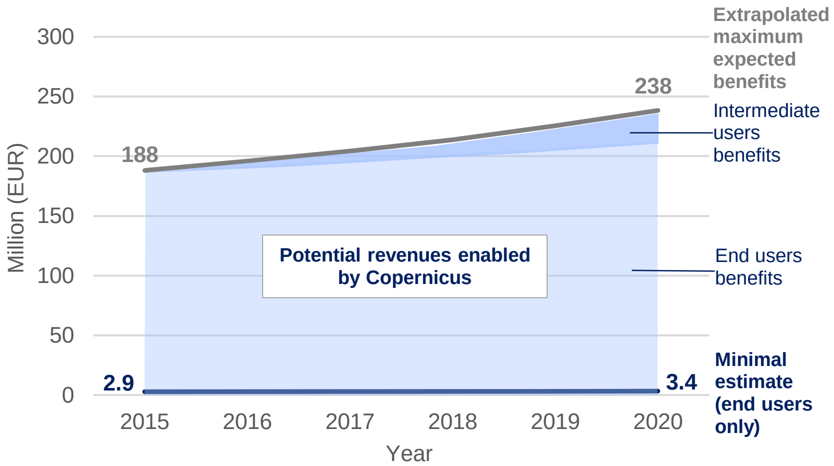

Figure 78 - Current and prospective enabled revenues by the availability of Copernicus data in Europe for the insurance sector (Source: PwC-Strategy& analysis)

Over the period 2015 – 2020, Copernicus-enabled revenues in the insurance value chain are forecasted to support a total estimated at **between 90 and over 6100 person years** in Europe. Most of the supported jobs are within the (re)insurance sector with up to 5600 person years.

It is assumed that productivity among the end users in the insurance sector was the same as for the industry NACE 65 and that productivity among the intermediate users was the same as for the industries NACE 62.01 and 62.02. The enabled employment estimation method used employment, output and GVA data from the Eurostat National Accounts (for NACE 65) and employment, turnover and GVA data from the Eurostat Structural business statistics (for NACE 62.01 and 62.02). The 2020 estimates were based on E3ME growth projections for these variables.

The different impacts of Copernicus across the (re)insurance value chain are summarised in the following table.

Table 39 - Synthesis of Copernicus socio-economic impacts – Insurance (Source: PwC-STRATEGY& analysis)

Economic	• **Lower financial risk (limited impact) through more accurate risks modelling, and therefore more accurate forecasts of the potential losses and indemnities. A slight increase of Copernicus contribution can be expected in the future.** • **Costs reductions (limited impact) through short term anticipation, internal organisation and optimisation of experts commissioning. The Copernicus contribution is not forecasted to increase in the future.** • **No additional revenues from parametric products as of 2016. However, Copernicus is forecasted to become a contributor in the future.**
Social	• Access by **remote and precarious population** to insurance products to support their agricultural activities against risks related to natural disasters. • Improved **quality of service** to insurers' clients: early warning for preparation and improved response delay after the event.
Environmental	• Statistical and reliable data about natural disasters events, for **scientific knowledge** and **political awareness**, to help better prevent future events.

Strategic	• **Improved interventions schemes for emergency services and civil protection through** large scale, dual optic/radar, reliable data for natural catastrophes mapping.

CASE STUDY

EO based NDVI insurance product for the Spanish market by Agroseguro

Context: The Spanish agricultural insurance system and Agroseguro

The current agricultural insurance system in Spain was created in 1980, and is based on a public-private partnership where the Government, private insurers and producers are represented through different bodies.
Agricultural insurance in Spain offers cover for damages caused to agricultural productions (crops and livestock), aquaculture and forestry due to:

- Unusual changes in the weather conditions.
- Diseases and accidents that involve death, obligatory slaughter, incapacity and even loss of a specific function of the animal.
- Forest fires.

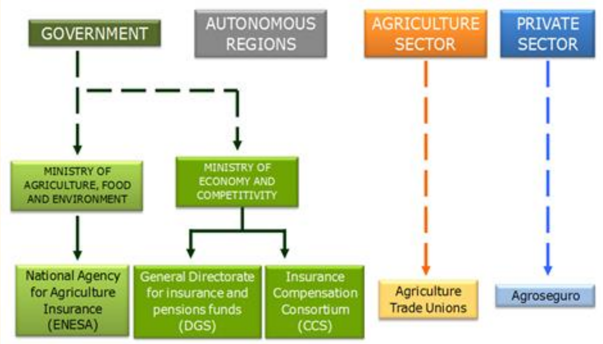

Figure 79 - Spanish agricultural insurance system

Currently, all agricultural and livestock productions can be insured against nearly all agro-climatic risks (crops), accidents and diseases (livestock). The producer's insurance cost is partly subsidized by the Central and Regional Governments. The agricultural insurance portfolio comprises 43 different insurance products (27 for crops, 12 for livestock productions, 3 for aquaculture productions and 1 for forestry).

The *Agrupación Española de Entidades Aseguradoras de los Seguros Agrarios Combinados S.A.* (**AGROSEGURO**) was founded as a joint-stock company in 1980. Its aim is to manage the agricultural insurance on behalf of the shareholding insurance companies. These companies, which are joint-stock companies as well as mutual companies, share the coinsurance pool that operates in the agricultural insurance market in Spain. Currently the pool is formed by 23 entities.

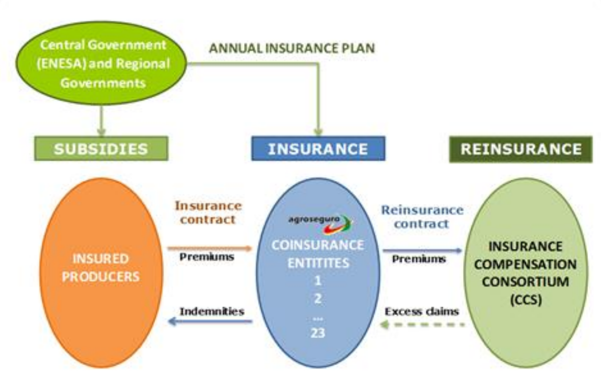

Figure 80 - Position of Agroseguro in the agricultural insurance mechanisms

Insured productions include crops, livestock, aquaculture and forestry. Based on its objective, the Company's principal activities involve:

- Representation of all co-insurance companies in the different fora and institutions involved in the Spanish Agricultural Insurance System;
- Comprehensive management of the whole insurance cycle (risks and viability analysis prior to the commercialization of new insurance products or covers, design of the insurance products, insurance policies management, and damage adjustment);
- Management of Reinsurance contracts on behalf of insurance companies.

Animal husbandry in Spain is distributed across the whole country and the three most important production types are **cattle, sheep and goats**. Up to 2001, livestock breeders could purchase various forms of insurance to cover death by various causes in order to counterbalance losses specifically in animal production. Livestock breeders were, however not covered against damage caused by the lack of pastures and they didn't know how to cope with the high costs of buying additional feed after a loss had occurred.

To counteract this situation, **insurance against lack of pastures was developed** within the Spanish insurance system in 2001, with the aim of offering stock breeders an additional instrument for farm management.

At the start, the aims were the following:

- To produce an effective instrument for the stock breeders to be able to cover the cost of feed for the animals over an extended period of lack of pastures and, therefore, guarantee their income;
- To design a simple product, both at the time of purchase and also when damage is evaluated;
- To make an objective system available for damage identification that is technically adapted to the type of risk.

Presentation of the project

Index insurance products are usually applied when covering large areas of the same production with a basic guarantee. This kind of insurance could provide a safety network to an entire sector. It is an instrument that seeks simplicity in its management, although it allows the differentiation of the guarantee levels according to zones that are homogeneous. It is also suitable to areas where farms do not employ very technically sophisticated working practices.

This insurance has gained perfection throughout the years thanks to the creation of databases that allow the progression towards insurances systems that are more specific and complex.

Even while being a tool which seeks especially simplicity in its model of management, the implementation of index insurance requires certain basic needs:

- Government support (subsidies to producers, information, etc.);
- A technological structure and technical knowledge to support the index system;
- A feasibility study with agronomical and meteorological data in order to establish a possible trigger with a proper level of confidence;

Administration & Operations costs for index insurances are quite low, although it is necessary to take into account the expenses of maintenance of the database and the technological structure to obtain the data upon which the index will be calculated.

The agricultural insurance portfolio in Spain only has one index product, which covers livestock breeders against the lack of pastures for feeding their cattle. The indemnity is calculated based on the extra cost for feeding animals when there are not enough pastures due to a climatic event (usually drought).

The index is the **NDVI (Normalised Difference Vegetation Index)**. The advantage of this index is not only that it is adapted to world-wide use but that it measures the quantity and lushness of vegetation. Its strength lies in recognising photosynthetic activity observed during the growth period, which is due to evaporation and the plants' being stressed. The vegetation index is all the greater when the plant is healthier and more active and, conversely, smaller if the plant is ill or less active.

Current contribution of EO to the NDVI

The vegetation index is calculated on the basis of normalised mathematical models. Obtaining the vegetation indexes is done in three clearly defined phases:

- Obtaining and processing the satellite images;
- Identifying areas of pasture land;
- Calculating the vegetation indexes on the basis of variables received;

Once the indexes are available, the risk premiums can be calculated in insurance product processing.

Over the past years, satellite images have proven to be an efficient means of investigating and monitoring areas hit by drought and other climatic events and its effects, at low cost. The vegetation index of the various homogenous grazing areas within the operative range can be measured by the satellite thanks to their electromagnetic radiation. The limited precision of these instruments was more than compensated by the size of the area under investigation. Also the excellent temporal resolution permits tracking the phenomenon's daily development.

During a first stage (2001-2009) **NOAA satellite images (from satellite NOAA 16)** were used to set the index, as that was the satellite that provided at that time the information (present and historical) needed for the insurance development.

Later, from 2010, insurance satellite images changed to **Terra & Aqua satellites (carrying the MODIS payload)**, as they had accumulated a sufficient historical record to feed the index insurance database. Also, these satellites provided more accurate information (better pixel resolution). Currently, the satellites make a **daily pass through the Iberian Peninsula**. Information by points ("pixel") is obtained with this satellite pass. **Each of the pixels has a size of 6.25 Ha** (250m x 250m).

Copernicus is not yet exploitable for this index insurance because it has not yet accumulated the necessary historical record needed to estimate the guaranteed index. In addition, some requirements related to pixel resolution and image frequency (temporal resolution) should be taken into account in order to consider Copernicus information as valid for use for lack of pastures index insurance. A forecast of the contribution that can be expected from Copernicus in the future is presented in the section "Copernicus forecasted enabled revenues".

Implementation process and challenges faced

First, it was necessary to set the areas where pastures grow in Spain. This was done by elaborating a map of land uses for pastures insurance based on CORINE Land Cover (developed by the EU). Once the pastures areas were identified, the scope of the insurance was divided into homogeneous pastures areas.

The regional average vegetation indices were calculated based on the pixels contained in each region. A study on the historical satellite data (from NOAA platform) for the different areas was carried out, to set the guaranteed index value.

The current vegetation index is calculated for each of the pixels chosen every ten-day period. Close collaboration with the **Remote Sensing Laboratory of the University of Valladolid** was established for the design and management the index insurance for pasture land in Spain. This institution is in charge of processing satellite images and provides the index data for each area. In addition, several studies were carried out in order to set the index that better fits the characteristics of the risk and production to be covered.

A pay out occurs when the vegetation index is lower than the guaranteed vegetation index (calculated as a percentage of the average index for the period 2000-2014) **during, at least, three ten-day periods**. Insurance conditions set different levels of claims, according to the severity of the damage.

The sum insured is calculated as the number of animals declared by the policyholder multiplied by the price per animal and species. The insured is not required to communicate the claim. He will be informed about a claim situation and the related indemnity.

Specific procedures accompanied the deployment of this index product. Clear information on the index and how it works was provided to the producers and a specific section in Agroseguro's website was created so any insured producer can access the information on the index situation in his area. Also, although the insurance is index-based, experts monitor the evolution of certain pastures areas on the field to check that index is in accordance with pastures situation on the field.

With regards to the training and development of specific expertise, though EO data is processed directly in the University of Valladolid, **experts in charge of designing and managing this insurance product were initially trained** to improve their knowledge in remote sensing and satellite images, and have increased their expertise on the matter over the years.

Two main challenges were identified during the development of the insurance product. The first challenge dealt with the **production characteristics of pasture land**:

- Grazing land's seasonal production depends on climate, soil property factors and farming system.
- There are great production differences within geographically small areas.
- One must allow for the fact that in Spain, farming is carried out by direct grazing, i.e. growth of the pasture occurs at the same time as the animals graze.
- Two main factors must be considered in the livestock breeder's farming system: herd size and type of grazing.

The second critical aspect was the **selection and calculation of the index**, which has to be as much correlated to the reality as possible, in order to minimise base risk.

An additional important parameter identified was the **availability of information** for the calculation of the index.

Enabled revenues and other impacts

In relation to the impact and results of pastures insurance in Spain, and in order to a better understanding of its performance, it is necessary to bear in mind certain **context elements**:

- **Public support** to agricultural insurance allows providing a high level of covers to producers making them affordable in terms of financial capacity;
- **Coinsurance system** allows private companies to cover risks that would be very difficult or even impossible to cover individually;
- Index insurance in Spain is developed as part of a whole agricultural portfolio including crops, livestock, aquaculture and forestry production. This allows **risk compensation and diversification** and enables to assume risk cumulus;
- Index insurance in Spain represents a small part of the total agro-insurance portfolio (2% of total premiums and 1% of total insured capital);
- Index insurance for pasture was developed with the aim of providing an **innovative solution to a producer's need** that could not be covered using the traditional damage adjustment methods;
- The specific characteristics of this type of insurances require **permanent technical and technological development**;

In this context, results of pastures insurance show a high variability, due to a **producer's risk perception,** technological changes (transition from NOAA to MODIS platform) and improvement of covers.

This insurance started in 2001 with very few insurance policies (63), as it was totally different and new for producers. There was a remarkable effort coming from public and private institutions to explain producers the characteristics and operation of this insurance product and in 2004 insured producers grew to almost 4,000. Highest number of insured producers (20,000) was reached in 2005, after a severe drought that affected the main pasture areas in Spain, which increased producer's risk perception.

Since 2010, when the insurance product is technically more evolved, underwriting remained more stable, **between 4,000 and 5,000 insurance policies per year**. Results are also more balanced.

In **2015**, there were around **4,200 insured producers and a total premium around EUR 11.5 million.**

The existence of this insurance has led to a reduction of the insured producers input costs related to climatic damage to pastures (mainly drought). **In 2005 more that EUR 65 million were paid to producers** to compensate the lack of pastures owing to a severe drought that affected main pastures areas. **In 2012**, drought hit again pasture land in Spain, and **indemnities to producers amounted to more than EUR 40 Million**.

For the period 2001-2015, total indemnities paid amounted to EUR 167.22 Million with more than 60,000 claims declared by producers.

Index insurance for pastures has also **social and environmental impact**, as it allows producers to maintain their farm's viability contributing to the rural economy, especially in those areas in Spain with pasture land that are considered as priority in terms of Rural Development policies.

Copernicus forecasted enabled revenues

Based on the number of premiums for a stable level of insurance policies such as 2015 at EUR 11.5 million (it can be noted that this value is in line with the average indemnities amount per year over 2001 – 2015), and considering the share of meadows and pastures in Spain with regards to Europe[254], a **broad estimate of the potential market value for livestock index insurance in Europe can be evaluated around EUR 516 million**. This value should be considered with precautions as the type and extent of natural disasters in each European country can vary significantly. The producers' risk perception plays an important role (as witnessed

[254] *Source: FAO statistics, http://faostat3.fao.org/home/E (retrieved 21/06/2016). Note: the data average over 10 years leads to a 2.23% share of meadows and pastures for Spain in Europe.*

in 2005 for Agroseguro) and therefore can influence the market size locally.

The remaining uncertainty on the market penetration of the Sentinels is linked to the technical capabilities the satellites.

One of the main advantages of Copernicus compared to MODIS is the image resolution. Copernicus provides a resolution of 20x20, which will allow a more accurate calculation of the index, particularly for homogeneous small pasture areas. Copernicus can provide the NDVI index through Sentinel-2A (by exploiting the spectral bands 4 and 8[255]) and also gives access to the data for free.

The revisit time of the Sentinels however is longer (5 to 6 days) than the Terra / Aqua satellites (1 to 2 days), which can affect the accuracy of the index, as there is a higher chance to not be able to get new pictures between 2 indexes computations (for instance due to cloud coverage).

Finally, the change of EO data source can also be a barrier for Copernicus, as it means moving towards a shorter data history and recalibrating a new index product.

Considering these aspects, it seems realistic to estimate that the Sentinels share of EO sources for index insurance will not exceed 1/3 of the total by 2025 (at this time the history will exceed 10 years), leading to **a highest value of revenues enabled by Copernicus around EUR 172 million for the European index insurance market in 2025**.

[255] *Source: ESA, https://sentinel.esa.int/web/sentinel/technical-guides/sentinel-2-msi/level-2a/algorithm (retrieved 21/06/16)*

Voice of Copernicus users[256]: SWOT

	STRENGHTS	OPPORTUNITIES
	• Sentinels technical capabilities (swath, resolution, and revisit frequency) are well adapted to index products. • Sentinels data offers SAR capabilities over similar sources of data (Landsat, Terra/Aqua). • Sentinels data have an easily customisable format for non-EO experts. • Sentinels data are reliable and trusted. • Open source data is an important factor in a price-sensitive sector such as insurance.	• Progressive growth of data history should increase the use of Copernicus for index products, capturing new markets (especially in developing countries). • Index products, for which Copernicus offers an adapted solution, should keep growing in the coming years. • Artificial reconstruction of data history could accelerate the rate of adoption of Sentinels' data. • Catastrophe modelling is perceived to still not be exploited at its real potential for crop and forestry insurance.
	WEAKNESSES	**THREATS**
	• Only a short data history is available for Sentinels satellites, involving continuity issues for risks modelling and index products. • Sentinels capabilities are lower than some commercial satellites which are preferred when quick images or a higher resolution are required for loss assessment. • The access to Copernicus data lacks transparency.	• Responsibilities and organisation for the storage of data in the coming years are not clear enough in order to make it exploitable by insurers. • Expertise required for indexes calculations restrains the number of potential providers. • Indexes computation remains a state of the art use of EO which is not yet fully reliable on the insurers perspective. • Improvement of EO capabilities and emergence of EO 2.0 players could change the rules about open source data and offer higher resolution images, at a higher frequency for free. • The adoption of other EO sources

[256] *PwC-STRATEGY& analysis, on the basis of interviews conducted in 2016 (cf detailed list of interviewees in the appendices)*

Policy recommendations to foster Insurance applications through Copernicus

Strategic pillar	Sectoral recommendations for policy action	Priority level
Pillar I: Ensure access to data	***#INS-1 – Build an "artificial history" for Sentinel data*** Most of the added value of the Sentinel data would come from index products, and the current barrier is the need for a long data history to be exploitable by the insurance sector. To accelerate this application, an investigation should be conducted on the technical means to constitute this history from the data available today and history of data from other sources.	1
Pillar I: Ensure access to data	***#INS-2 – Support the creation of a platform oriented on insurers' customised needs*** As non-EO experts with specific needs, (re)insurers would benefit from a tailored access to EO data with a dual function: the manipulation of data to turn it into insurance inputs and the focal point of the different exploited sources, both open source and commercial.	2
Pillar I: Ensure access to data	***#INS-3 – Centralise the open data sources to provide an open access service with increased responsiveness*** The interest in EO data for loss assessment strongly relies on the responsiveness after the event, which could be increased by mutualising several sources including the Sentinels.	3
Pillar II: Support innovation	***#INS-4 – Stimulate the adoption of satellite images by initiating the trainings and information on key principles*** The current use of Copernicus remains very limited partly due to the lack of know-how on satellite images processes. (Re)insurers often rely on themselves (and the willingness of their people to take the "EO step") to become familiar with the existing sources, platforms, acquisition processes and technical knowledge on data format, manipulation and customisation. This know-how, though elementary, stands as a prohibitive barrier in some cases, and can be easily overcome, and is the opportunity to promote Copernicus by adapting the provided trainings to the Copernicus ecosystem. Some trainings on these principles would save a lot of energy, time and money for (re)insurers, which could then focus on their internal transformation.	1
Pillar II: Support innovation	***#INS-5 – Support R&D works around index products to democratise their use*** The financial viability of index products for (re)insurers relies on the correlation between the index and the reality. This correlation represents a state-of-the-art knowledge about EO data, and tends to restrain both the interest of insurers in such products (reliability and cost) and the number of potential VAS company providers (high expertise and cost).	2
Pillar II: Support innovation	***#INS-6 – Clarify and ease the process to apply for EC grants*** The procedure to apply for EC grants and funds for Copernicus related initiatives is perceived as bulky, demanding in terms of time and energy, and lacking of transparency, especially for SMEs	3
Pillar III: Increase awareness	***#INS-7 – Anticipate the storage and archiving responsibilities for Sentinel data*** The process and responsibilities for the storage and archiving of Sentinel data should be clarified in anticipation of the future use of the data by VAS companies and (re)insurers. This task is not perceived by insurers to be included within their scope.	2
Pillar III: Increase awareness	***#INS-8 - Develop partnerships and collaborations between VAS companies and insurers*** In order to bridge the gap between the insurers' needs and EO experts' capabilities, partnerships should be encouraged. The aim would be both ensuring that the dialogue includes small actors and when necessary bringing financial support to the collaboration.	2

Ocean monitoring

Key specificities
➢ **The ocean monitoring domain encompasses a wide range of activities characterized by significantly different needs: these include sustainable fishing and the protection of marine resources, ocean surveillance and coastal protection, extraction of natural resources (minerals, energy, etc.), commerce and trade.** ➢ **Intermediate users of EO data related to ocean monitoring issues are private companies of various sizes (from micro-companies to large companies), public authorities, research centres or laboratories.** ➢ **End users of applications based on EO data are both from the public (ministries, local governments, laboratories, sea authority centres, authorities in charge of marine conservation) and private sectors (fish farmers, farming cooperatives, etc.).** ➢ **EO revenues for the ocean monitoring sector amounted to EUR 103.85 Million in 2015, and among those, EUR 5.76 Million can be directly attributable to Copernicus.** ➢ **Increasing opportunities for EO projects and services exist in countries located outside of Europe concerned by specific ocean-monitoring issues (like Indonesia, which has a pressing necessity to monitor fishing and marine biodiversity).** ➢ **The ocean environment is characterized by rapidly changing parameters (for example, changes related to weather conditions), requiring very precise data and information – such as near-real time data – which makes EO data an important source of information.** ➢ **The ocean monitoring sector will be the primary sector impacted by Sentinel-3 data.**

Scope/boundary

Activities related to ocean monitoring encompass the monitoring of the ocean itself (ocean streams, water quality), what is in the ocean (as marine resources), vessels which are on the ocean. This chapter mainly focuses on activities aimed at monitoring the status of marine biodiversity, encompassing mapping of fishing zones, aquaculture as well as activities related to coastal protection. Monitoring of oil slippage and of transportation traffic (such as vessels monitoring) are not included in the scope of our analysis because they have already been tackled by EARSC throughout a case study funded by ESA. Indeed, this case study was published very recently in the framework of assessing Copernicus Sentinels' Products Economic Value. It describes the whole value chain on winter navigation in the Baltic[257], on which the analysed product has an impact including icebreakers, ships, ports, factories and consumers.

Taxonomy and definitions

The *Marine and Ocean* downstream domain include all maritime-focused applications whether natural or human-oriented[258].

Main definitions related to the agricultural value chain	
Aquaculture	Aquaculture is the farming of aquatic organisms: fish, molluscs, crustaceans, aquatic plants, crocodiles, alligators, turtles, and amphibians. Farming implies some form of intervention in the rearing process to enhance production, such as regular stocking, feeding, protection from predators, etc. Farming also implies individual or corporate ownership of the stock being cultivated. For statistical purposes, aquatic organisms which are harvested by an individual or corporate body which has owned them throughout their rearing period contribute to aquaculture, while aquatic organisms which are exploitable by the public as a common property resource, with or without appropriate licences, are the harvest of capture fisheries.[259]
Blue economy	This concept has its origins in the growing awareness of the important of the

[257] *EARSC. 2015. Copernicus Sentinels' Product Economic Value: A Case Study of Winer Navigation in the Baltic. [ONLINE] Available at: https://issuu.com/earsc/docs/case_report_-_winter_navigation_in_/1?e=22610110/32044487. [Accessed 17 June 2016].*

[258] *According to EARSC taxonomy*

[259] *Fisheries and Aquaculture Department. 2010. CWP Handbook of Fishery Statistical Standards. [ONLINE] Available at: http://www.fao.org/fishery/cwp/handbook/J/en. [Accessed 12 June 2016].*

	damages on ocean ecosystems caused by human activity and can be defined as the moment when economic activity is in balance with the long-term capacity of ocean ecosystems to support this activity and remain resilient and healthy.
Marine Biodiversity	The variability among living organisms from all sources, including, inter alia [among other things], terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part: this includes diversity within species, between species and of ecosystems.[260]
Marine Protected Area (MPA)	A space in the ocean where human activities are more strictly regulated than the surrounding waters - similar to parks we have on land. These places are given special protections for natural or historic marine resources by local, state, territorial, native, regional, or national authorities. Authorities differ substantially from nation to nation[261].
Ocean economy	The economic activities that directly or indirectly take place in the ocean, use outputs from the ocean, and put the goods and services into the ocean's activities.[262]

Value chain description

Overview of industry/domain

The ocean covers 7/10 of the planet, is on average approximately 4,000 meters deep and contains 1.3 cubic kilometres of water[263]. With each European citizen consuming around 20kg of fish products per year, fish is one of the world's most important sources of food.[264] Hence, monitoring ocean related activities efficiently is necessary in order to ensure its sustainability.

260

261 Protect Planet Ocean. 2010. Protect Planet Ocean is about Marine Conservation. [ONLINE] Available at: http://www.protectplanetocean.org/collections/introduction/introbox/mpas/introduction-item.html. [Accessed 12 June 2016].

262 Kwang Seo Park. 2014. A study on rebuilding the classification system of the Ocean Economy. [ONLINE] Available at: http://centerfortheblueeconomy.org/wp-content/uploads/2014/11/10.29.14.park_.kwangseo.the_ocean_economy_classification_systemfinal_21.pdf. [Accessed 5 April 2016].

263 Ocean Explorer. 2014. The Pacific Ocean is the largest and deepest ocean basin on Earth, covering more than 60 million square miles (155 million square kilometers) and averaging a depth of 13,000 feet (4,000 meters).. [ONLINE] Available at: http://oceanexplorer.noaa.gov/facts/pacific-size.html. [Accessed 16 June 2016].

264 Lorna Inniss, Alan Simcock, Amanuel Yoanes Ajawin, Angel C. Alcala, Patricio Bernal, Hilconida P. Calumpong, Peyman Eghtesadi Araghi, Sean O. Green, Peter Harris, Osman Keh Kamara, Kunio Kohata, Enrique Marschoff, Georg Martin, Beatrice Padovani Ferreira, Chul Park, Rolph Antoine Payet, Jake Rice, Andrew Rosenberg, Renison Ruwa, Joshua T. Tuhumwire, Saskia Van Gaever, Juying Wang, Jan Marcin Węsławski. 2016. The First Global Integrated Marine Assessment World Ocean Assessment I. [ONLINE] Available at: http://www.un.org/Depts/los/global_reporting/WOA_RPROC/WOACompilation.pdf. [Accessed 11 April 2016].

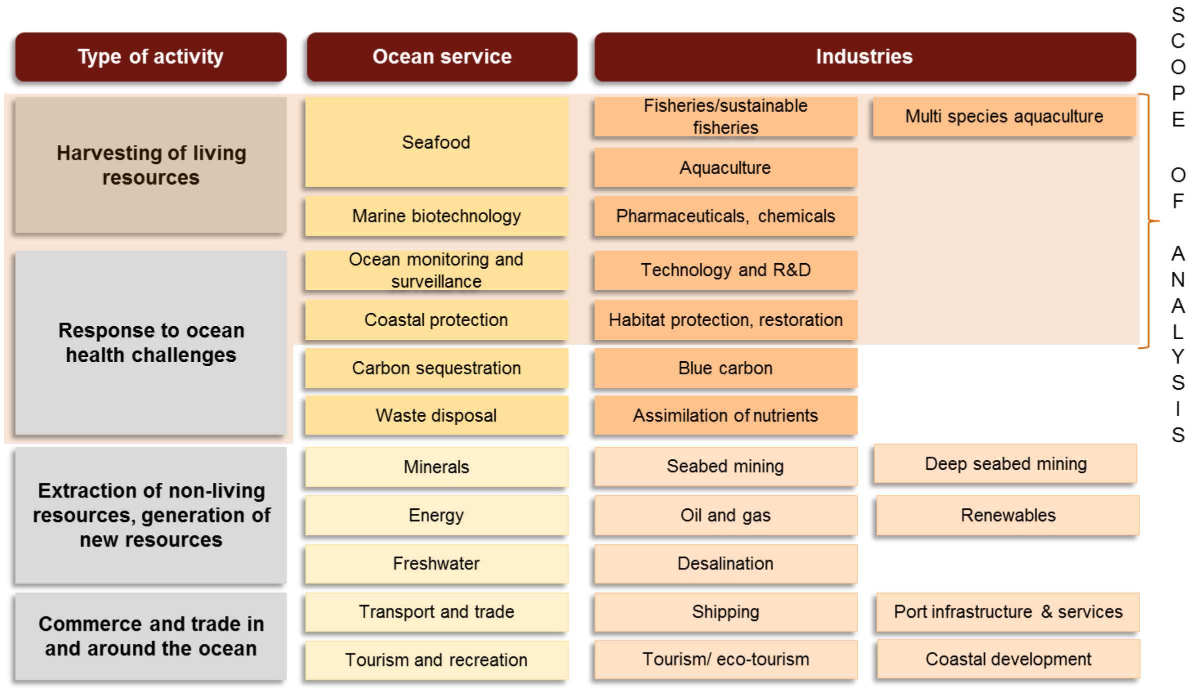

Figure 81 - Components of the ocean economy (Source: the Economist Intelligence Unit)

Overall, four main types of activities can be identified within the ocean economy: (1) **harvesting of living resources**: monitoring of marine resources, mapping of fishing zones, etc.; (2) **response to ocean health challenges**: ensuring coastal protection, ocean monitoring and surveillance via the detection and management of oil spills; (3) **extraction of non-living resources and generation of new resources** such as minerals, energy resources and freshwater, etc.; (4) **commerce and trade in and around the ocean**: linked to the transportation by vessels as well as tourism. As outlined in the section above, this analysis will only concern two of the above mentioned activities: harvesting of non-living resources and response to ocean challenges, since oil and gas related issues will be tackled in the correspondent section of this report and commerce and trade in and around the ocean have been addressed by the previously mentioned EARSC case study.

The ocean is a global economic resource. The total contribution of ocean exploitation to the global economy is challenging to assess, because coastal and ocean economies are sometimes blurred. Some regional data do exist: in 2014, **China's ocean economy is reported to having contributed to 10% of the GDP**, employing 9 million people throughout the country[265]; in Europe, fishing and fish processing provide jobs for more than 350,000 people[266]. The importance of the ocean's economy combined with the difficulties to monitor the ocean (linked to the rapid changes of ocean conditions due to the weather, ocean currents, etc.) make EO data particular useful in this context since satellite derived data can provide accurate, near-real time and reliable data over large geographical areas.

The ocean is also a major source of food, thus representing a major area of focus for food security issues. As an example, 4,806 thousand tonnes of fish were captured in the EU in 2013[267]. Therefore, ensuring sustainable fishing and the continuity of fishing activities is a necessity, which is why the Food and Agriculture Organisation (FAO) has defined 27 specific fishing areas to facilitate mapping of fishing zones per area[268]. Today, several major factors, mainly resulting from the impacts of global warming and of human activity, deeply threaten the ocean ecosystem:

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[265] *Rui Zhao, Stephen Hynes , Guang Shun He. Defining and quantifying China's ocean economy. Marine policy Vol. 43, January 2014. Link: https://www.dimar.mil.co/sites/default/files/atach/10.defining_and_quantifying_chinas_ocean_economy.pdf.*

[266] *Copernicus, 2013. Satellites Support Sustainable Fishing. Prepared by ESA and the European Commission. September 2013. No. 34.*

[267] *Eurostat. 2015. Total catches in selected fishing regions, 2003–13. [ONLINE] Available at: http://ec.europa.eu/eurostat/statistics-explained/index.php/File:Total_catches_in_selected_fishing_regions,_2003%E2%80%9313_(%C2%B9)_(thousand_tonnes_live_weight)_YB15.png. [Accessed 16 June 2016].*

[268] *FAO, 2016. CWP Handbook of Fishery Statistical Standards, Section H: fishing areas for statistical purposes. [ONLINE] Available at: http://www.fao.org/fishery/cwp/handbook/H/en.*

pollution, decreasing fish stocks and illegal unreported and unregulated fishing activities. In addition, losses due to illegal unreported and unregulated or pirate fishing are estimated to be between USD 10 billion and USD 23.5 billion per year in the world[269]. EO data can contribute to better control the fishing zones in order to ensure sustainable fishing and avoid any food security issue.

Value chain characterization from an EO data usage standpoint

Current use of EO data

(M EUROS)	Overall EO downstream market	% of the overall market for ocean monitoring	EO downstream revenues for ocean monitoring
2012	786	16.50%	129.69
2015	911	11.40%	103.85

Table 40 - EO downstream revenues in Europe for the ocean monitoring sector (Sources: EARSC; PwC-Strategy& analysis)

Ocean monitoring-related issues account for one of the most important sectors in terms of revenues within the European EO market. However, revenues generated by ocean monitoring-related products decreased by approximately 20% between 2012 and 2015 (refer to the table above for further information). Among the ocean monitoring sub-sectors, the revenues which decreased most are related to marine ecosystems.[270] This could be explained by the fact that end users most concerned by marine ecosystems products are rather public oriented (such as research centres, laboratories, universities, etc.). Hence the budget available to purchase EO related products might have significantly decreased, no longer providing the possibility for public end users to resort to such applications.

The aforementioned table gives a conservative estimation of the value of the EO downstream market based on EARSC figures. In order to obtain a higher estimate, it would be useful to take the value of the GIS market on the whole provided by Technavio[271], as stated in the below table. By deducting the portion of the value of the EMEA market related to the Middle East and by taking into account only the products related to services and data, the value of the market could be estimated at EUR 1,352 Million, significantly higher than the EO downstream market. Considering that the portion of applications related to ocean monitoring is similar for the GIS market than for the EO market, the high estimate of the GIS revenues related to agriculture would account for EUR 154.12 Million, which corresponds to an additional 48% from the value of the EO downstream revenues for agriculture.

(M EUROS)	Overall GIS market for Europe	% of the overall market for ocean monitoring only	GIS revenues related to ocean monitoring
2015	1,352	11.40%	154.12

Table 41: GIS revenues in Europe for the ocean monitoring industry (Sources: Technavio; EARSC; PwC-Strategy& analysis)

During the past decade, the ocean community witnessed the launch of over **30 new ocean-related satellite missions by 13 different contributing space agencies** representing around 36 countries[272]. Ocean monitoring related activities highly benefit from EO data: target end users are in need of highly precise, near real-time and accurate information to monitor very specific features of the ocean such as ocean streams, variations due to the weather, the force of the wind, etc. which makes it increasingly difficult to monitor, and provide reliable forecasts, nowcasts and hindcasts.

Specifically, EO products developed by VAS companies benefit key activities in the ocean economy: regarding **aquaculture and fisheries**, the use of EO data is highly beneficial to **map fishing zones**. As a matter of fact, fisheries are regulated in order to prevent fish stocks to collapse via specific regulations such as the Common

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[269] *MESA. 2015. EARTH OBSERVATION, FISH AND FOOD SECURITY IN AFRICA. [ONLINE] Available at: http://rea.au.int/mesa/node/162. [Accessed 12 June 2016].*
[270] *Based on figures provided by EARSC.*
[271] *Technavio. Global GIS Market 2016-2020. 2015.*
[272] *IFREMER, 2013. Nephelae: a platform for data intensive science - an application to ocean. Link: http://wwz.ifremer.fr/bigdata/Exemples-de-problemes-en-oceanographie/Nephelae-a-platform-for-data-intensive-science-an-application-to-ocean.*

Fisheries Policies (CFP) in Europe. As an example, some rules can limit the amount of fish from a particular fishery in order to ensure its sustainability. As such, data related to sea-surface temperature or ocean colour data can give indications to fish farmers on where and what to fish and enable public authorities to perform inventory of aquaculture and fishery structures. To sum up, EO data contributes to implementing sustainable fishing practices by enabling a more efficient management of fish stocks.

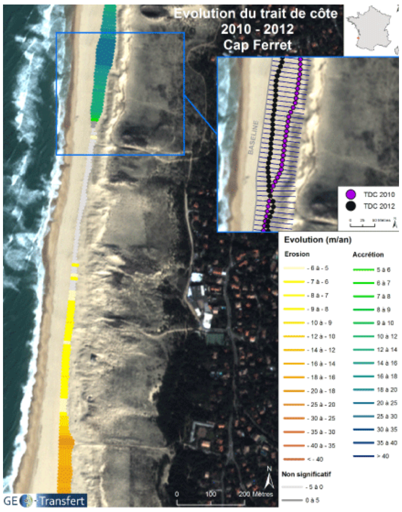

Figure 82: Overview of a coastal monitoring application based on EO data (Source: I-sea)

EO data also contributes to **improve practices for protection of aquatic species and marine biodiversity** and adds value to research on species movements and behaviours: scientists use environmental variables such as temperature, chlorophyll, depth of the sea, information related to the wind in order to better assess the biological characteristics of the ocean and thus assist in the mapping of marine protected areas that protected species favour for foraging. The models developed by service providers combine remote sensing data with ecologically variables in order to obtain specific information related to the protection of aquatic species and marine biodiversity. As an example, coral reef managers[273] use environmental information, such as sea-surface temperature, to improve the monitoring of conditions and threats to reef ecosystems in order to minimize the potential impact on humans and support reef health; a concrete application along these lines is the Coral Reef Watch (CRW) from the National Oceanic and Atmospheric Administration (NOAA), which is an online tool providing near-real time and long-term monitoring, forecasting and reporting of environmental conditions of coral reef ecosystems throughout the world. This specific application is developed via combination of satellite data, climate models and in situ tools[274].

The favourable biophysical and climatic conditions and the opportunities coming from navigation have historically encouraged human settlement in coastal zones. Today, coastal zones often concentrate a high level of economic activity encompassing aquaculture, fisheries, shipping, tourism, etc.[275], which makes coastal protection a pressing issue. EO data contributes to **coastal protection** throughout the monitoring and prevention of coastal erosion, obtaining a better overview of the coastline's morphology in order to prevent the formation or destruction of offshore sandbanks or beaches. As an example, satellite data captures the depletion of vegetation and changes in the littoral dunes as an indicator of dune erosion both as a result of storms and of long term effects[276]. Satellites such as Envisat's Medium Resolution Imaging Spectrometer (MERIS) characterizes the complex missing of pollutants, suspended sediments and living and decomposing phytoplankton[277].

Another highly important aspect in which EO information is absolutely necessary is in **monitoring the distribution of the phytoplankton and inorganic settlement in view of monitoring Harmful Algal Blooms** (HABs). This specific application is detailed in the case study "Forecasting algal blooms: the ASIMUTH project", reported below.

The end users benefiting from EO related products are of two types: public sector users on one hand, which represent approximately 80% of total user base, and private end users on the other hand which represent approximately 20% of the base[278]. In the public sector, local public authorities use EO data to monitor coastal

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[273] The core managers group in charge of managing and ensuring the protection of coral reefs is referred to as coral managers. In some countries, they are grouped in dedicated entities – in Australia for example, the government has set up the 'Great Barrier Reef Marine Park Authority'.
[274] CEOS, JAXA. 2015. Satellite Earth Observations: Serving Society, Science & Industry. [ONLINE] Available at: http://ceos.org/document_management/Publications/Data_Applications_Report/DAR_All-Chapters-Final_27Oct2015.pdf. [Accessed 13 June 2016].
[275] FAO. 1998. Integrated coastal area management and agriculture, forestry and fisheries. [ONLINE] Available at: http://www.fao.org/docrep/W8440e/W8440e02.htm. [Accessed 26 May 2016].
[276] Booz&co, 2014. Evaluation of the socio-economic impacts from space activities in the EU.
[277] ESA. 2015. Coastal zones. [ONLINE] Available at: http://www.esa.int/Our_Activities/Observing_the_Earth/Space_for_our_climate/Coastal_zones. [Accessed 12 June 2016].
[278] These figures are approximations that have been calculated thanks to the quantitative data collected throughout the stakeholders' consultations.

erosion for example. Public research institutions such as IFREMER, the French Institute for Research and Exploitation of the Sea, national agencies in charge of monitoring fishing stocks for example, ministries in charge of ecology and cities are the principal clients of EO applications. Within the private sector the main end users are the fish farmers, or wider fish farming corporations which disseminate the products amongst the individual fish farmers.

The figure below summarizes the main applications of EO data in the ocean monitoring sector:

Type of applications	End users	Benefits
• Mapping of fishing zones	• Fish farmers • Public authorities	• Facilitates the performance inventory of aquaculture • More efficient fishing
• Mapping of marine protected areas	• Public authorities • National agencies • Research centers	• Improved protection of aquatic species and marine biodiversity
• Monitoring and prevention of coastal erosion	• Local public authorities (cities)	• Better prevent the coastal erosion (such as the destruction of beaches)
• Forecasting algal blooms	• Local authorities • Fish farmers • National agencies	• Increase productivity • Limit the waste of contaminated shellfish
• Monitoring reef ecosystems	• Coral reef managers	• Facilitate decsion-making to protect coral ecosystems • Facilite the conduct of extensive monitoring

Figure 83 - Synthesis of EO applications in ocean monitoring (Source: PwC-Strategy& analysis)

Market structure and trends

The number of companies active in the European market for ocean monitoring-related EO products accounted, in 2012, for approximately 12% of the total number of companies active providing EO based services. The two sub-sectors in which most companies are active are marine ecosystems (accounting for 46% of the total number of companies operating in the EO market related to ocean monitoring) and companies operating in the field of the coastal sub-sector (accounting for 36%[279]).

In terms of structure, our market analysis combined with the stakeholders' consultation enabled us to characterize the market as follows: the **intermediate users encompass a couple of large players with a large market share, and a majority of smaller players (micro companies and SMEs) as well as several public institutions** (such as research institutions, etc.).

Examples of private companies include the French company "Collecte Localisation Satellites" (CLS), a French company of 520 people created 30 years ago as a subsidiary of the French Space Research Centre (CNES), that provides operational services for environmental monitoring, sustainable management of marine resources and maritime security. CLS is considered as being one of the pioneers of VAS providers in the ocean monitoring field, which started developing its expertise in the field of spatial altimetry in 1995. Smaller players include companies such as Isardsat, a rapidly growing European SME which started off 10 years ago with 2 experts and which counts today 23 staff members. According to the stakeholders' consultation, a **vast majority of intermediate users from the private sector do not focus solely on developing applications related to the ocean monitoring sector**, because the demand from end users is not sufficient to ensure stable revenues.

Intermediate users from the public sector include **laboratories** such as the Plymouth Marine Laboratory (PML), a publicly funded laboratory focusing on marine-related issues, providing, in some cases, commercial services to private end users such as farming companies.

[279] *PwC – STRATEGY& analysis based on EARSC figures*

Mercator Ocean, one of the leaders in the EO market in terms of ocean monitoring-related applications, is an example of a public/private entity providing services to end users. Indeed, Mercator Ocean is a privately-owned but non-profit company funded by five French institutions involved in operational oceanography: CNRS (National Centre of Scientific Research), IFREMER, IRD (French Institute for Research and Development), Meteo-France and SHOM (the hydrographic and oceanographic service of the French Navy)[280]. Mercator Ocean is also responsible for the implementation of the **Copernicus Marine Environment Service (CMEMS)**.

According to our analysis and the stakeholder's consultation, the segmentation of the market can be broken down as follows:

- 30% of end users focus on security and maritime transportation issues, in order for example to optimize maritime routes ensure security (such as the sea conditions that may pose a risk).
- 30% are concerned by the marine environment such as the quality of the water which is defined by biophysical characteristics. This type of information is useful for users focusing on research activities.
- 30% are related to weather and climatology, meaning the link between the ocean and the meteorological system.
- 10% of users tackle marine resources issues such as fisheries, in order to better map fishing zones for example

Geographically speaking, there are rising opportunities for VAS companies in emerging markets in countries which are concerned by ocean monitoring-related issues such as the mapping of marine protected areas or the protection of coral reefs, due to the impact of climate change. Indonesia, by being the 3rd producer for captured fisheries, and by being the 4th aquaculture producer worldwide, could highly benefit from EO based applications.[281] In this context, the "INDESO" project involves some of the major players of the downstream market such as CLS and Mercator Ocean and is currently being implemented. This project is aiming at establishing a forecasting and management centre for marine resources that will enable to predict changes in fishery resources. This should enable to foster a sustainable used of marine resources in Indonesia while preventing unsustainable or illegal practices which undermines these resources.

The products developed are of various types: images, maps focusing on various specific issues depending on what the clients' need is: mapping of fishing zones, focus on the colour of the ocean, frequency maps to assist in mapping marine protected areas, dynamic maps to monitor coastal erosion, tailored products on specific issues. As an example, i-Sea, a French micro-company, enables its clients to monitor the position of the coastline regularly in order to evaluate and mitigate the risks posed by coastal erosion and marine submersion. The Plymouth Marine Laboratory (PML) provides regular bulletins to Scottish farming companies during the growing season of harmful algal blooms in order for them to better anticipate their arrivals. Other types of products include forecasts (from days to weeks), and hindcasts of ocean state over long-time series in the past. These products are sometimes complemented by explanatory reports to assist the end users in understanding them and thus better exploit the applications.

Table 42 - Key drivers and obstacles in the Ocean monitoring EO market (Source: PwC-Strategy& analysis)

Key Drivers	Key Obstacles
⬀ The ocean is particularly challenging to monitor via in situ data because of its rapidly changing characteristics (weather, currents, temperature, etc.). Hence, this creates potential opportunities for intermediate users to reach out to clients that could benefit from EO solutions in this context.	⬂ The **combination of EO data with in situ data requires very strong and specific skills in-house** from service providers which represents a very significant investment in terms of cost and time and can thus hold back several service providers from developing such applications.

[280] *MercatorOcean. 2015. Ocean forecasts & analyses. [ONLINE] Available at: http://www.mercator-ocean.fr/en/mercator-ocean/company/. [Accessed 13 June 2016].*

[281] *Ministry of Economic Affairs of the Netherlands, 2016. Stimulating the uptake of space data, European examples that inspire us.*

Ocean monitoring encompasses numerous sub-sectors which concern a wide range of end users (fish farmers, ministries, local authorities, research centres, etc.). Hence, this provides opportunities in order for service providers to develop a **wide range of applications on mapping of fishing zones, coastal protection, mapping of marine protected areas, etc.**	**Most clients of ocean-related EO products are non EO-experts** and not aware of the potential benefit of applications based on EO data. This can be a significant barrier for service providers to access the market and requires important marketing and communication efforts.
Several emerging trends, such as the **impact of global warming on oceans and more specifically on marine resources**, the **growing necessity to manage fish stocks** via the European "Total Allowable Catches" (TACs) and encourage sustainable development create additional opportunities for service providers.	

Data flow along the value chain

The following sections describe the data flow along the value in terms of the type of necessary data for ocean monitoring-related products, the platforms available, the processing of the data in view of developing software and specific products as well as the type of end users.

Data collection and processing platforms

Due to the diversity of end users and VAS products developed within the ocean monitoring value chain, the type of EO data required can be quite diverse. In terms of geographical coverage for starters, considering the diversity of the end users and their widespread location, intermediate users need for EO data to have the widest geographical coverage possible. The highest revisiting time possible is necessary for applications providing information on the state of the ocean which require rapid decision making from the end users. Medium Resolution is the most appropriate type of resolution for most of the applications developed in the field of ocean monitoring. Intermediate users need to have a global vision of the ocean with, for some cases, a focus on several zones of the ocean (such as coastal areas). As an example, applications that deliver information on the protection of marine biodiversity can have a 5 kilometre resolution, whereas, monitoring water quality is best done with a 300 metre resolution.

Two main types of data are used by service providers, with an important focus on near real-time data. Firstly, all types of satellite data (mainly SAR data and optical data) coming both from public and private satellites such as: **JASON satellites** for altimetry and an improved monitoring of climate change related issues of the ocean, **NASA satellites** such as the National Oceanic and Atmospheric Administration (NOAA), **METOP** (Meteorological Operational Satellite Program of Europe), **Cosmos**, **Radarsat**, etc. **Sentinel data** are being integrated by intermediate users – at the moment, Sentinel-1&2 data only, with a high expectation for Sentinel-3 for altimetry and products related to ocean colour. Satellite data is systematically combined with in-situ data which is collected thanks to very precise oceanographic sensors to obtain physical, oceanographic, bathymetric, geophysical, meteorological data. When needed, satellite data and in situ tools can also be combined with climate models in order to include highly precise data on water temperature for example.

Intermediate and/or end users use various platforms which deliver specific data and/or services related to ocean monitoring issues. The **CMEMS** provides regular reference information on the state of the physical oceans and regional seas throughout the production of observations, forecasts and re-analysis for example. According to the stakeholders' consultation, this Copernicus core service has currently approximately 6000 users. The IFREMER has its own data processing platform, **Nephelae**, which is a cloud system used for scientific research purposes. This research centre also provides data via "Oceanflux data" which are accessible freely and can be exploited by intermediate users to develop revenue generating services. **SeaDataNet** is a pan-European standardized system for managing the large and diverse data sets collected by the oceanographic fleets and the automatic observation systems. This infrastructure links 90 national oceanographic data centre and provides data on all of the European seas.

Outsourced and in-house EO capabilities

The service providers which started developing EO applications in the ocean monitoring sector did so approximately in the 2000s. Since then, many VAS companies have had the opportunity to develop competences and skills in-house throughout trainings and the recruitment of specialized experts. In some cases, VAS companies have proceeded to the acquisition of smaller players specialized on specific issues. Service providers hence quite rarely recourse to outsourcing and most of the activities in view of developing value-added applications based on EO data are performed in-house.

Development of value-added software, products and applications

VAS companies use a combination of EO and *in-situ* data to develop their products and value-added services. Indeed, according to a recent study performed by ERISS Corporation and the Maritime Alliance during which 410 US companies of the ocean economy sector were solicited, 68% of the intermediaries informed that they generally used *in-situ* data versus EO data[282].

In most cases, **software and products are developed in-house by EO experts and oceanographers**. In other cases, VAS companies build **partnerships with specialised software developers**. VAS companies also use products that are made available on the CMEMS platform. Service providers often work in collaboration with other types of actors such as specialised consultancies, academic institutions to provide innovative solutions and enlarge their range of clients and develop new commercial strategies. Local SMEs also tend to develop partnerships with similar types of structures to start off activities abroad. When needed and if the opportunity arises large VAS companies acquire specialised companies to boost their competitiveness on the market. As such, CLS has acquired a company specialised in radar imagery in order to benefit from additional expertise.

End users

Ocean monitoring-related products and applications developed by VAS companies benefit a wide range of public end users: most of them are from **governmental entities** such as ministries and agencies (ministries of ecology, maritime affairs, coast guards, etc.). **Researchers from laboratories, scientists** are in great need of EO information to complement their research activities on very specific themes (such as the protection of marine resources, marine biodiversity, etc.). Some other actors from the private sector, like civil engineering companies or fish farmers for example, use VAS products and applications on ocean monitoring.

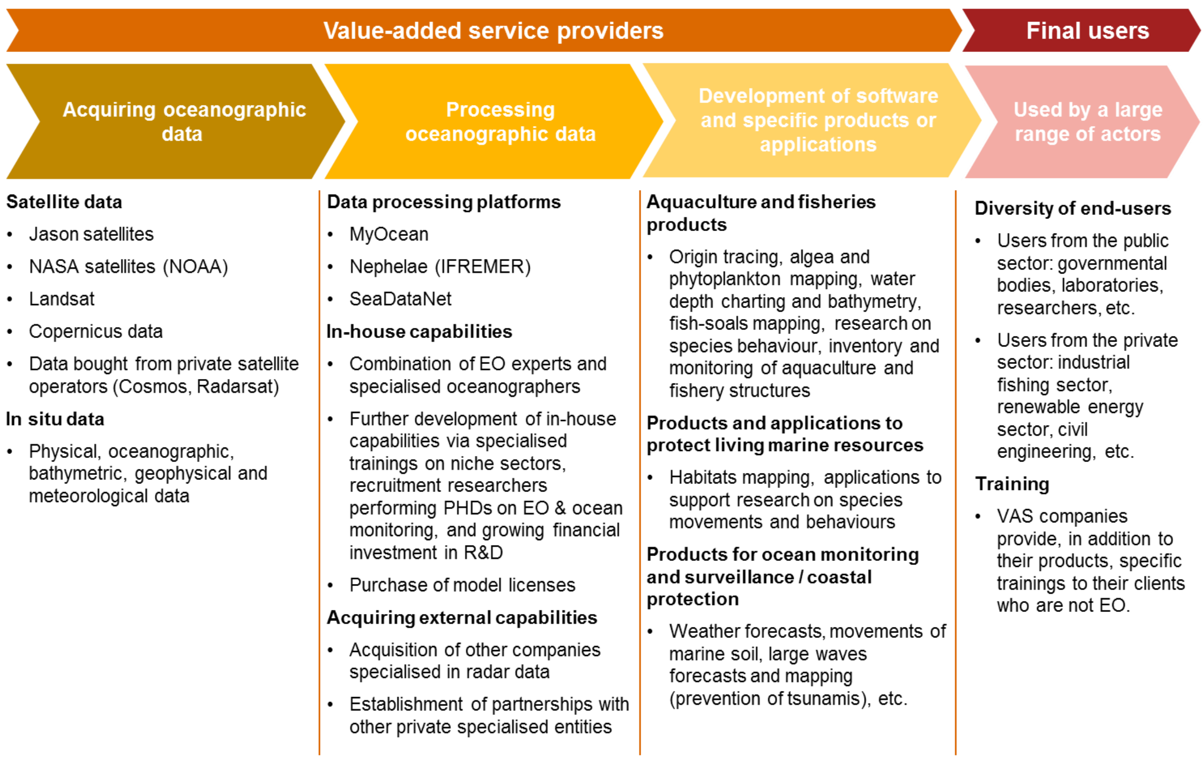


Figure 84 - Data flow along Ocean monitoring value chain (source: PwC-STRATEGY& analysis)

Current role of Copernicus

According to the stakeholders' consultation, approximately 60% of the intermediate users currently use Copernicus data. However, Sentinel-1 & 2 data are used **for very specific activities related to ocean**

[282] *ERISS Corporation, the Maritime Alliance. The ocean enterprise, a study of US business activity in ocean measurement, observation and forecasting. 2016. Link: http://www.ioos.noaa.gov/ioos_in_action/oceanenterprise_feb2016.pdf*

monitoring: water quality, detection of micro bacteria, roughness features associated with sewage outflows for example. Several service providers are using Sentinel-1 & 2 data for research purposes.

All of the surveyed companies have indicated that they are **planning on using Sentinel-3 data as soon as they become available**. Sentinel-3 indeed has the appropriate technical specifications for ocean monitoring-related issues: it will provide wide-swath ocean colour data as well as accurate and precise data on sea-surface temperature. Sentinel-3 data shall hence add value to the following products: sea surface height products, ocean colour products, wind and wave tracking products, sea ice products, sea surface temperature products.

ESA and EARSC case study on the economic benefits of Copernicus on winter navigation[283]

A case study was performed by ESA and EARSC in view of assessing the economic benefits derived from Copernicus Earth Observation (EO) data on the case of winter navigation in the Baltic where satellite radar imagery is used to support the ice-breaking services of the Finnish and Swedish Maritime Administration. This report looks more specifically at a radar product which is based on Sentinel 1 data and its use to support winter navigation in the Baltic. Finland and Sweden was chosen as a case study because they are the countries on which the product has the most extensive impact.

The ice breaking services include several actors in Sweden and Finland: the Finnish Transport Agency (FTA), the Swedish Maritime Association (SMT), Arctia Shipping, the Finnish Meteorological Institute (FMI). The product value chain on the other hand takes into account 6 tiers: the primary service provider, icebreakers, ship operators, ports& harbours, stevedores and logistics, businesses, and the general public.

The analysis performed enabled to underline the fact that the availability of satellite imagery has had significant impacts on the Finnish economy and that it has led to a number of concrete benefits. For icebreakers for example, the availability of satellite imagery has enabled to reduce fuel consumption and to abolish usage of helicopters: the total icebreakers fuel costs savings of Finland and Sweden to be in the range of €10.5m (Finland €6m and Sweden €4.5m) corresponding with an average of just under €1m per year. In terms of cost savings due to the abolishment of usage of helicopters stationed on-board, they amount to approximately EUR 14.26 million over the last 11 years, corresponding to an average of EUR 1.3 million per year. Ships on the other hand benefit from significant fuel cost savings, savings in operational costs due to reduced transit and waiting time, savings due to a decrease in ice related damages (repair costs and insurance costs). Port and logistics have three types of benefits: port savings, stevedores' savings, and logistics savings. Factories and the local economy have three kinds of benefits: reduced stocking costs, greater customer confidence, production efficiency. Regarding the citizens, the estimated economic benefits is quite extensive. Finally, the total economic return, based on the assumptions defined, would, for Finland and Sweden combined, of at least EUR 24.2 million per year.

The Copernicus Marine Environment Service

The Copernicus Marine Environment Monitoring Service (CMEMS), which can be defined as "an integrated, sustainable, reliable, open, and free service providing access to a single catalogue of products", was implemented by the European Commission jointly with ESA and the European Environment Agency (EEA). This core-service provides a sustainable response to European user needs in four main areas: maritime safety, marine resources, coastal and marine environment and weather (forecasting and climate). This unique service worldwide provides regular reference information on the state of the physical oceans and regional seas throughout the production of observations (description of the current analysis), forecasts (the prediction of the situation a few days ahead) and re-analysis (the provision of consistent retrospective data records for recent years). These products support all marine applications: the provision of data on currents, winds and sea ice contribute to marine safety via the improvement of ship routing services, offshore operations or search and rescue operations. The products developed are classified by region (Global, Baltic Sea, Atlantic European North West Shelf-Ocean, Atlantic- Iberian Biscay Irish- Ocean, Mediterranean Sea) and then by type of information provided by the product (sea level, ocean colour, sea surface temperature, sea ice, wind, in situ).

The CMEMS is an important contributor of the dissemination of the data emanating from the Copernicus programme within the ocean monitoring value chain. Indeed, as outlined in previous sections, the CMEMS currently has approximately between 5000 and 6000 users, 80% from which emanate from the public sector. Approximately half of the users are scientific users. The other half is composed of professional users which use this data to develop commercial services: among those, approximately 20% very strongly need this information.

[283] *EARSC. Case report, winter navigation in the Baltics. 2015*

The following table provides an overview of the main products elaborated by the CMEMS:

Region/ Type of product	Name of the product	Detail
Global ocean	Global Ocean Biogeochemistry Analysis and weekly forecast	This product is developed by Mercator Ocean which provides a 7 days mean global forecast updated weekly as well as 3D global ocean biogeochemical weekly mean analysis for the past 2 years updated every week.
Arctic Ocean	Arctic ocean physics reanalysis	This product provides 3D physical ocean and sea ice variables for the time period 1991 - 2013
Atlantic-European North West Shelf- Ocean	Atlantic- European North West Shelf- Ocean Biochemistry Reanalysis from METOFFICE (1985-2012)	The reanalysis is based upon the Forecasting Ocean Assimilation Model 7km Atlantic Margin Model. This is a coupled hydrodynamic- ecosystem model of the North West European shelf forced at the surface by ERA- interim winds, atmospheric temperature, and precipitation fluxes.
Mediterranean Sea	Mediterranean Sea Biogeochemistry Analysis and Forecast	These products are produced by the OGS Production Unit and provide seven days of analysis/hindcast and ten days of forecast, produced twice per week on Wednesday and on Saturday. Data assimilation of surface chlorophyll satellite observation is performed once a week.
Sea level	Mediterranean Sea L4 gridded MAPS NRT SLA	For the Mediterranean Sea - Multi altimeter satellite gridded sea surface heights computed with respect to a twenty-year mean. All the missions are homogenized with respect to a reference mission which is currently Jason-2. The acquisition of various altimeter data is a few days at most. This product is computed with a non-centred computation time window (6 weeks before the date).
Ocean Colour	North Atlantic Surface Chlorophyll Concentration from Satellite observations	Daily products are available in near real-time (NRT) and few days after in Delayed Time (DT), which is of better quality since it uses hindcast meteorological and navigational data.
Sea surface temperature	Mediterranean Sea High Resolution and Ultra High Resolution Sea Surface Temperature Analysis	The data are obtained from infra-red measurements collected by satellite radiometers and statistical interpolation. It is the MyOcean sea surface temperature nominal operational product for the Mediterranean Sea.

Table 43 - Main products from the Copernicus Marine Environment Service (Source: marine.copernicus.eu)

Copernicus socio-economic impact assessment

The identification of the socio-economic impacts of the Copernicus programme within this study was performed through a stakeholder consultation based on a survey and on dedicated interviews with a sample of stakeholders from the ocean monitoring value chain: six private companies of different sizes and one national research centre also delivering commercial services to private clients.

Copernicus current enabled revenues

(M EUROS)	EO downstream market for ocean monitoring	% of Copernicus enabled revenues	Copernicus downstream revenues for ocean monitoring
2015	103.85	5.55%	5.76

Table 44 - Copernicus enabled revenues for ocean monitoring sector (source: PwC – Strategy& analysis)

The quantification of the revenues attributable to Copernicus was done on a sample of 9 service providers (public and private) delivering very diverse services on a wide range of sectors in order to represent the current market at best: coastal protection, marine biodiversity, support to aquaculture, mapping of marine protected resources, etc. According to the analysis, **Copernicus current enabled revenues account for 5.55% of the EO downstream market for ocean monitoring, meaning 5.76 Million Euros**.

One first important element to single out is that the **study was performed at an early stage of the Copernicus programme**, which may explain why the current enabled revenues directly attributable to Copernicus may appear to be, at this stage, quite low. Indeed, just 16.6% of the stakeholders' interviewed have indicated currently using

Sentinel-1 and/or 2 data. In addition, another significant element that should be singled out is the unavailability of Sentinel-3 data at the time of the study. Sentinel- 3 missions have technical specifications which are particularly appropriate in the field of ocean monitoring and will provide highly accurate and reliable information on sea surface height, ocean colour, sea surface temperature, tracking of wind and waves, etc.

Copernicus data has enabled service providers to **decrease slightly their production costs** by replacing data bought from private satellites with free Sentinels data. Indeed, the data coming from the Russian Kosmos and Canadian Radarsat satellites are very expensive – the cost of an image ranging between EUR 1,000 and EUR 5,000[284].

Copernicus current non-monetary benefits

In terms of social impacts, the Copernicus programme has **created knowledge within clients benefiting from ocean-related products and applications** based on EO data. As an example, CLS, which has started developing EO products related to mapping of fishing zones in 2000, has indicated that, initially, most of their clients were not EO experts: they required specific assistance and in some cases training to be able to use at best the information delivered by the service providers. Over time, the end users gradually gained experience in using value-added services and acquired expertise in order to integrate EO data in their activities. In addition, the information delivered by the CMEMS providing biophysical characteristics of the marine environment increased the knowledge on these specific issues of the CMEMS users, half of which are non EO experts, as previously stated in the previous section.

The end users interviewed have also underlined that the services developed using Copernicus data **boost sustainable fishing and limits environmental nuisance**. Indeed, thanks to EO data, fish farmers better target fishing zones and thus improve their productivity and efficiency: they are able to fish a more important amount of fish in a more limited timeframe[285]. As an example, the "I-fishSAT system" implemented by ESA is a trading platform providing real-time fisheries data and enables to trace fishing activities. EO data will be used more particularly to estimate sea parameters and derive meteorological information in view of elaborating forecasts. The particular added value of EO data is that it will support the identification of the most productive areas in order to optimize the fish catch strategy.

[284] Stakeholder consultation
[285] The quantification of the productivity gain is done more precisely in the case study in the section below.

CASE STUDY

Forecasting Harmful Algal Blooms for fish and shellfish farmers The ASIMUTH project

Context of the project – Harmful Algal Blooms (HABs)

About 300 different types of algal blooms exist – such as phytoplankton blooms, micro-algal blooms, toxic algae, red tides. A quarter of these blooms is known to produce toxins and is referred to by the scientific community as being Harmful Algal Blooms (HABs).

HABs occur when colonies of algae, which can be defined as simple plants that live in the sea and freshwater, grow extensively and produce toxic or harmful effects on their environment (humans, fish, shellfish, etc.). They mostly occur when water temperatures are high and when the water contains nutrients such as nitrogen and phosphorus, depend on ocean currents, surf conditions, and wind speed and direction. They can appear in marine, estuarine and fresh waters as well as along coastlines and surface waters.

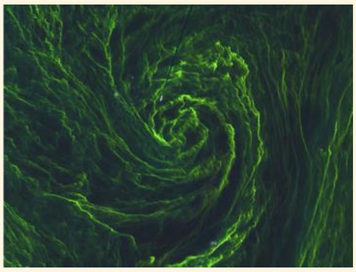


Figure 85 - Eye of an algal bloom captured by Sentinel-2A (Source: ESA)

HABs can have significant negative impacts on their environment: they can make shellfish and fish toxic, cause massive farmed fish kills throughout Europe and human illnesses. As an example, one single toxic bloom caused the loss of 500,000 salmon in Shetland, an archipelago in Scotland. Such incidents are sporadic and largely unpredictable. Studies have reported that approximately 6% of harmful algal blooms may cause fish mortality. Scientific researchers distinguish two main types of HABs: toxin producers, which can contaminate seafood or kill fish on one hand, and the high biomass producers which can be responsible for an absence of oxygen and important kills of marine life.

Being a natural event, HABs cannot be prevented. But understanding the occurrence and movement of Toxic Algal Blooms is a key commercial / economic factor in marine aquaculture enterprises and in the context of several leisure activities linked to tourism. Better anticipating and monitoring the occurrence of HABs could potentially lead to many cost saving.

Indeed, with 1.25 million of fish or finfish being produced every year, the EU is the 8th biggest producer in terms of volume of aquaculture in the world, with the top 7 aquaculture species being: Mussel, Trout Salmon, Oyster, Carp, Sea Bream and Sea Bass[286]. With 85,000 people directly employed in the European aquaculture sector, marine aquaculture is practiced in every costal member state of the EU. The figure highlights the growing important of the aquaculture industry in Europe. Most of the increase can be explained by the significant production of salmon over the past decade. All these elements underline the importance of establishing an effective and reliable HAB monitoring system throughout Europe.

The ASIMUTH project: HABs forecasts based on Copernicus

this context, the "ASIMUTH" project (Applied Simulations and Integrated Modelling for the Understanding of Toxic and Harmful Algal Blooms) has been set up in order to respond to the demand for **short-term forecasts of harmful algal blooms events along the European Atlantic coast**s, using EO data.

[286] *European Commission. 2016. Aquaculture in the EU. [ONLINE] Available at: http://ec.europa.eu/fisheries/documentation/publications/2015-aquaculture-facts_en.pdf. [Accessed 14 June 2016].*

The ASIMUTH project brings together a European consortium of 11 scientific institutions and businesses mixing research institutions (such as the Irish Marine Institute and the French IFREMER) and companies (including Starlab, a Spanish-based company providing value adding services based on EO data, and Hocer SAS, a French company developing and producing water analysis systems for the protection of all drinking water resources.

The project tracks the origins of algal blooms using remote sensing satellite data and monitoring images of chlorophyll and water temperature. **The project downscales the products of the Copernicus Marine Environment Service (CMEMS) and integrates these products with biological data with input from HABs experts to produce warning bulletins to aquaculture producers**. The products are delivered in the internet and on mobile devices and allow customers to make viable commercial plans to reduce the commercial impact of these blooms.

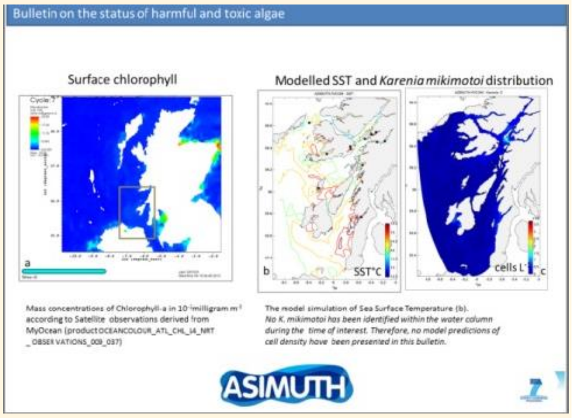


Figure 86 - Scottish HAB bulletin excerpt (Source: Asimuth project)

The project initially started in 2009 with a series of initial steps comprising a series of technical and scientific objectives which enabled the modelling of physical and biological interactions leading to the forecasting of toxin events, fish mortalities or ecological disruption from HABs. The partners of the consortium worked together in order to address shared problems.

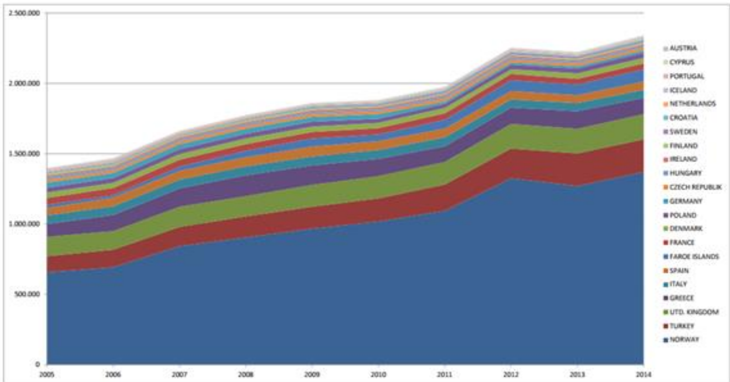


Figure 87 - Development of Fish Farming in Europe (tons) 2005 – 2014 (Source: *FEAP. 2015. European Aquaculture Production Report 2005-2014*)

The different scientific aspects of ASIMUTH can be summarised as:

- The identification of **key past events** which were re-analysed and used to test the modelling system
- The incorporation of the **Copernicus Marine Core Service (CMCS)** with the key past events identified and used to develop model based hindcast products in order to make the model more operational and efficient to forecast events
- The designation of **regional model systems and delivery of nowcasts** for specific HABs and location information, transport pathways, remote sensed data.
- An indication of **the population of HAB-distributed decision support system** from various data streams (such as phytoplankton, biotoxin, satellite, etc.)
- Provision of **experts' interpretation of the available data** by way of the web portal which was carried out on a periodic basis depending on risk.

The CMEMS is a cornerstone to the project: it is absolutely necessary to obtain very accurate and real-time data in order for the experts to build accurate HABs forecasts. There currently is an unprecedented flow of information on the European ocean from the Marine Core Service (MyOcean) using mechanisms such as Model Forecast Centres (MFCs) and Thematic Assembly Centres (TACs) distributed throughout Europe. Furthermore, ASIMUTH is the first project to operationalize elements that were before solely research elements.

Copernicus enabled revenues for fish and shellfish farmers

HABs caused the closing of bays for harvesting and left farmers to wait until the bay re-opened. These closures could last for several months, causing extensive production losses. Thanks to the ASIMUTH project, a forecasting system for HABs in the European Atlantic was developed, as well as innovative models and strategies to improve sustainable utilisation of fish and shellfish, by integrating a wide range of data to understand the functioning of algal bloom movements.

The ASIMUTH project has had sound economic impacts: **the provision of accurate HABs forecasts has enabled fish farmers to increase their productivity by approximately 5%**, by optimising harvesting schedules and installing appropriate aeration systems. Indeed, an early warning system for blooms gives producers the chance to change their practices by installing oxygenation systems, moving their stocks, harvesting their fish earlier, etc.

More specifically, the forecasting system implemented within the ASIMUTH projects targets to reduce the losses caused to the mussel industry by at least 12.50% in five target countries: France, Spain, the UK, Ireland and Portugal. According to an analysis performed by the ASIMUTH consortium (see Figure below), the average total losses in the mussel industry in these countries amounts to USD 20,745 million (i.e. EUR 18,290 million). Considering that the 12.50% of savings are reached thanks to the ASIMUTH project, it would represent a potential saving of USD 2,593 million (i.e. EUR 2,292 million).

Country	Average Total Losses due to HABs ($)	Potential Savings due to ASIMUTH if 12.5% of losses are recouped ($)
France	9,556,919	1,152,029
Spain	6,320,046	758,718
UK	2,658,419	337,535
Ireland	2,197,607	284,091
Portugal	12,179	1,616
TOTAL	20,745,170	2,593,146

Figure 88 - Value of savings due to ASIMUTH for the mussel industry (Source: ASIMUTH consortium)

Before the implementation of the project, HABs caused the mortality of **8,000 tons of fish per year (corresponding to EUR 31.3 million)** and extensive losses from the fish farms. Today, the forecasting system is considered as being close to **100% in terms of accuracy**, and is expected to improve continuously thanks to perpetual improvement of the accuracy of the system, meaning that it should prevent the loss of a significant amount of fish. Indeed, the early warning of severe HABs has allowed fish and shellfish farmers to adapt their culture and harvesting practices in time in order to prevent potential losses due to contaminated fish. On the longer term, a more adapted and efficient harvesting strategy has allowed fish farmers to increase their productivity.

According to the FAO, the demand for fish consumption is expected to grow substantially – it should rise by 30% between 2010 and 2030. Hence, in order to face this increasing demand, the five target countries need to build reliable and sustainable fish farming strategies in order to face any upcoming challenges. The ASIMUTH project additionally aims at providing the necessary tools, on the mid to long term, for the fish farmers to respond accurately to this demand.

In addition, a **performant HAB monitoring system would enable fish farmers to limit wasting shellfish** that contain toxins since specific regulations prohibit the right for fish farmers to sell them. Indeed, a predicted harmful bloom would avoid fish farmers to harvest their fish in the first place.

Better monitoring HABs **reduces production costs of fish farmers through insurance deductibles**. Indeed, if the protocols are not in place and mortalities occur, the insurance company refuses to pay. If they are just partially in place, the insurance company pays only 60% of the loss of stock.

Non-monetary benefits thanks to preventing HABs with Copernicus

The production of forecasts has enabled improved management practices within fish farms by providing farmers with vital and key decision making inputs. As an example, by appropriately anticipating the HABs events, farmers can take the **appropriate decisions to prevent their fish from suffering from any toxic effects** (such as piling their products in advance). The combination of the know-hows and expertise of the different partners of the consortium has allowed them to reach improved management strategies towards the impact of HABs with a particular focus on the sustainability of wild and farmed finfish and molluscan bivalve fisheries (clams, oysters, scallops, etc.).

In terms of market challenges, the aquaculture sector is increasingly exposed to international competition in the fish and shellfish sector. Competition comes strongly from Asia (China and Japan), South America (more particularly Chile), New Zealand and America (Canada and the US). A combination of increased productivity and improved management practices will boost the supply of fish sustainably and **limit price fluctuations**

for raw material. Thus, fish farmers will be in a better position to tackle international competition which characterizes the aquaculture sector.

The ASIMUTH project also has social impacts. Via its integrated forecasting system, it has enabled fin fish and shellfish farmers to **acquire knowledge on the best practices to monitor HABs and to prevent** them from being contaminated by toxins. Hence, the fish harvested is of better quality and has better nutritional intakes which translate into positive impacts on public health.

This monitoring and forecasting system for HABs can also have positive impacts for other end users than shellfish and fin fish farmers. Indeed, **better monitoring HABs can also lead to preventing potential negative impacts on activities linked to tourism**. Some HABs can cause foams which float in the ocean that can end up on beaches, which may be very unsightly in tourist spots. By better anticipating HAB, the appropriate authorities can minimize the impact of such events on tourist activities.

Copernicus projected contribution to the global and European socio-economic impacts

(M EUROS)	EO downstream market for ocean monitoring	% of Copernicus enabled revenues	Copernicus downstream revenues for ocean monitoring
2015	103.85	5.55%	5.76
2020	116.96	23.85%	27.89

Table 45: Minimal estimation of Copernicus current and projected revenues for ocean (Source: PwC - Strategy& analysis)

While the current enabled revenues directly attributable to the Copernicus programme are yet limited, 90% of the stakeholders' interviewed have indicated that they anticipate an increase of the enabled revenues directly attributable to Copernicus, to come mainly following the launch of Sentinel -3. Indeed, all of the stakeholders interviewed have indicated that they are planning on integrating Sentinel- 3 data as soon as it becomes available.
Hence, according to extensive stakeholder consultation, the projected contribution of Copernicus to downstream EO revenues would be of approximately 23.85% (minimal estimation) of the total EO downstream market for ocean monitoring. Using the assumption that a, a conservative estimate of the value of Copernicus data in 2020 is of approximately EUR 27.89 million.

In order to provide a high estimate of the total revenues directly attributable to Copernicus in the ocean monitoring sector, the analysis was performed on the basis of the GIS market. For methodological purposes, the shares attributable to the EO downstream market were considered as being similar for the GIS market. In order to obtain a high estimate for 2020, since EARSC does not provide the evolution of the portion of the applications related to agriculture against the total amount of applications, the methodology chosen was to take into account the fact that the European GIS market for 2015 corresponded to 2.08 times the EO market for 2015. Hence the GIS revenues for ocean monitoring applications is estimated to be of EUR 243.28 Million in 2020, with Copernicus downstream revenues to be of **EUR 58.02 Million**, corresponding to more than double of the minimal estimation.

(M EUROS)	Overall GIS market for ocean monitoring	% of Copernicus enabled revenues	Copernicus downstream revenues for ocean monitoring (high estimation)
2015	154.12	5.55%	8.55
2020	243.28	23.85%	58.02

Table 46: High estimation of Copernicus current and projected revenues for ocean monitoring (Source: PwC - Strategy& analysis)

The **ocean monitoring sector will be the primary sector that will be impacted by Sentinel- 3 data**. The accuracy, high resolution and repetitiveness of Sentinel-3 data will allow VAS companies to gradually use it instead of private satellite data: this will cause an **important decrease of production costs** as well as **an improvement of the quality of the products delivered**. As an example, the integration of Copernicus data in products focusing on spatial bathymetry will enable one of the SMEs interviewed, which has a significant experience in developing EO based applications, to produce an image on the basis of EUR 90 to EUR 95 per square km in comparison with their current production cost which is of EUR 200 per square km, using Landsat data. The production cost should be 10 times less than when using Lidar data.

Hence, reducing the production costs will allow intermediate users to offer more affordable products of higher quality (providing more precise and more reliable data). Service providers therefore anticipate a facilitated market penetration in order to reach additional clients in a period from 5 to 10 years.

The integration of Sentinel-3 data will also foster the **development of new products** on a wider range of sub-sectors concerning ocean-related issues: to monitor marine biodiversity for example, the use of Sentinel-3 data will enable to improve the level of granularity by detecting species or at least groups of species. The creation of these products will boost the competitiveness of the VAS companies and will have an impact on the distribution of the market, with a higher proportion of private users.

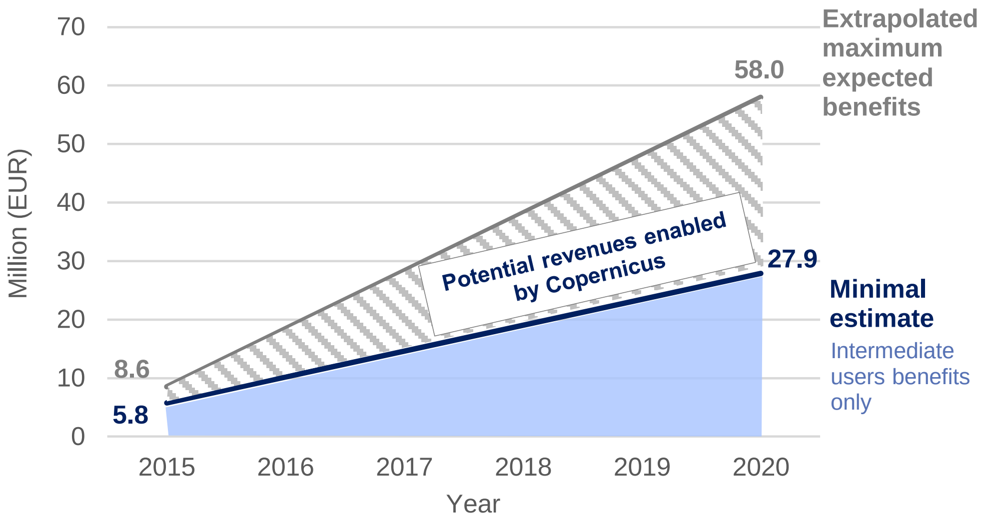


Figure 89: Current and prospective enabled revenues by the availability of Copernicus data in Europe for ocean monitoring (Source: PwC- Strategy & analysis)

Over the period 2015 – 2020, Copernicus-enabled revenues in the ocean monitoring value chain are forecasted to support a total estimated **between 780 and 1540 person years** within the EO and GIS downstream markets across Europe.

It is assumed that productivity among the intermediate users was the same as for the industries NACE 62.01 and 62.02. The enabled employment estimation method used employment, turnover and GVA data from the Eurostat Structural Business Statistics. The 2020 estimates were based on E3ME growth projections for these variables.

The different impacts of Copernicus across the (re)insurance value chain are summarised in the following table.

Table 47 - Synthesis of Copernicus socio-economic impacts - Ocean monitoring (source: PwC-Strategy& analysis)

Economic	• **The Copernicus downstream revenues for ocean monitoring-related issues account for EUR 5.76 Million and are expected to increase with the launch of Sentinel-3.** • **The integration of Sentinel data has enabled end users (here fish farmers) to increase their productivity (by 5% in the case of the ASIMUTH project)** • **Stakeholders using Sentinel-1 & 2 data use it for very specific issues: water quality, detection of micro bacteria, roughness features** • **Copernicus data has enabled service providers to decrease their production costs since it replaces data bought from private providers** • **The availability of Sentinel-3 data should cause significant cost savings and thus increase commercial benefits. Indeed, one SME indicated that**

	it should be able to reduce the production cost by more than 50% by replacing data bought from private satellites with Copernicus data (expected) • **Sentinel-3 data should also enable service providers to improve the quality of existing products thanks to the accuracy, high resolution and repetitiveness of the data (expected)**

Social	• The Copernicus programme has **created knowledge within the ocean monitoring sector**, by providing a flow of free data to service providers

Environmental	• The quality and reliability of Sentinels data adds value to **sustainable fishing and limits environmental nuisance** by allowing fish farmers to better target fishing zones

Voice of Copernicus users[287]: SWOT

STRENGHTS

- Data sources for ocean-related issues are diversified and the quantity of data available is increased via the Copernicus programme which will add value to applications focusing on mapping of fishing zones, monitoring harmful algal blooms, etc.
- The Copernicus programme contributes to rendering EO "mainstream" in the ocean monitoring sector and has made its afferent market more aware of the potential benefits of EO in ocean monitoring-related activities.

OPPORTUNITIES

- Sentinel-3 data will enable VAS companies to obtain much more precise and appropriate ocean colour data to monitor marine biodiversity for example.
- Thanks to Sentinel-3 data, VAS companies will develop improved products thanks to the technical specifications which are particularly appropriate in the ocean sector, which will enable them to increase their competitiveness on the market.
- Sentinel-3 data will enable service providers to reach out to more clients (such as local fish farmers for example), by proposing more affordable qualitative services.

WEAKNESSES

- Copernicus is programmed to be European-focused, a strong obstacle for exportation since many potential end users are located outside of Europe, and more specifically in countries with important sea surface areas to manage (ie. Indonesia).
- Collecting information on ocean-related issues is difficult and costly due to the remoteness of many regions and the harsh conditions under which data collection systems operate.
- The information delivered by the CMEMS does not always respond to the needs of the end users, in the sense that they lack interconnectedness and relevance in some cases.
- Specific technical constraints hinder the collection of reliable, frequent information since EO data can be provided within limited time windows.

THREATS

- Start-ups or micro companies which provide ocean monitoring-related issues do not necessarily have the financial resources to invest in the required infrastructure to archive the important amount of data.
- In order to better respond to the needs of the end users, service providers will need to find a way to differentiate effects that are due to natural causes from the effects due to humans. As an example, several applications can detect major ocean changes linked to the colour of the ocean, water pollution, etc, but do not have the level of detail or expertise to identify the source of these changes.

[287] *PwC-STRATEGY& analysis, on the basis of interviews conducted in 2016 (cf detailed list of interviewees in the appendices)*

Policy recommendations to foster Ocean monitoring through Copernicus

Strategic pillar	Sectoral recommendations for policy action	Priority level
Pillar I: Ensure access to data	#OCE-1 – Provide support to SMEs developing ocean-related applications for data access issues Micro-companies, SMEs or start-ups developing applications related to ocean monitoring do not necessarily have the financial resources to invest in the appropriate infrastructure to archive the important stream of data provided by the Sentinel missions. One possibility would be for the **EC to assist them in finding solutions to process and compute the available data.**	2
Pillar II: Support innovation	#OCE-2 – Boost discussions between the EC and the private sector **The market for EO products related to ocean monitoring issues is yet not sufficiently mature.** Stakeholders from the private sector recommend increased discussions with their counterparts from the public sector and more specifically the EC in order for them to better respond to their needs.	1
Pillar III: Increase awareness	#OCE-3 – Increase the visibility of EO applications Ocean monitoring encompasses a wide range of sub-sectors (mapping fishing zones, monitoring illegal fishing, ensuring marine biodiversity, etc). Thus, many potential end users are not necessarily fully aware of the variety of services that their activities could benefit from. In response, **public authorities should strive for an increased knowledge and visibility of the applications and products** developed by service providers.	1
Pillar III: Increase awareness	#OCE-4 – Develop university courses There is a sound lack of technical knowledge regarding EO-related issues and oceanography. As a consequence, service providers can sometimes have difficulties in finding the appropriate resources with the relevant knowledge for their activities. The establishment of **specific university courses and technical trainings** could be a solution **to render EO mainstream in the ocean monitoring field**.	2
Others	#OCE-5 – Encourage international cooperation between ocean-related systems Stakeholders within the ocean monitoring field are in need of highly precise and accurate data, which cannot always be provided by satellit[2]e data. One solution would be to **boost international cooperation in order to establish a global and integrated vision of continental hydrological systems**, via for example multi-faceted programmes bringing together hydrologists, climatologists, river basin agencies, etc.	2

Specific recommendations for the **CMEMS**:

Others	**#OCE-6 – Integrate the CMEMS with the other Copernicus core services** **End users sometimes need highly specific data that is not always provided by the CMEMS. By being increasingly integrated to the other Copernicus core services, the CMEMS would be able to better respond to the needs of these users and provide them with the diversity of data they need (such as the waves height).**	1
Others	#OCE-7 – Help the CMEMS to contribute to the qualification of main trends Stakeholders from the ocean monitoring sector need precise information regarding main trends of the ocean. Thus, **the CMEMS should better contribute to the qualification of main trends and identification of major changes in the ocean**: today, the data provided does not enable to differentiate normal from abnormal phenomenon. In order to do so, streams of past data have to be processed, which is yet not possible for SMEs.	2

Oil and Gas

Key specificities
The O&G value chain is, among the ones chosen for the study, one of the most commercially-oriented, and the one showing the highest level of enabled revenues associated to the Copernicus programme at this stage. In study analysis scope, it was indeed chosen to focus on the private side of the oil and gas industry. ➢ **The analysis carried out in this value chain focuses on private end users from the upstream O&G industry. While several public end users are also involved in this market (governmental agencies in charge of surveying prospective areas for exploration and mapping national resources, governmental agencies in charge of oil spill monitoring and oil spill response, etc.) only private end users were considered in the analysis, in order to maintain a stronger focus on commercially-driven activities and on enabled revenues** ➢ The upstream O&G industry is heavily impacted by **the recent fall of oil's price** which is **negatively impacting EO-data and products adoption in general (including Copernicus data and products):** the O&G industry can be characterised as traditional and risk averse in the adoption of new processes and practices, and this includes new products such as Copernicus. ➢ **The usage of EO data within the O&G upstream industry varies a lot from one actor to another but in general, the use of EO is quite widespread among upstream O&G end users compared to other mostly commercially-driven value-chains. Interesting initiatives by ESA were developed in the field of O&G to foster the dissemination and the use of EO data.** ➢ **O&G represents a significant stream of revenues for European EO downstream players; however, the largest value is ultimately created by the O&G end users. The largest share of value derived from the Copernicus data and products in the sample under scrutiny is derived from O&G end users, and not from intermediate users.** ➢ Most of the industry **have already switched to the GIS products & services**. Upstream O&G actors are in most of the cases **using imagery incorporated in more complex GIS products**, including EO (all resolution), UAVs data (when national regulation allows it use), in-situ data, internal data and statistics, etc.

Scope/boundary

The preliminary literature review on the Oil and Gas (O&G) sector has pointed to the upstream and midstream part of the value chain as the main recipients and users of EO data. With the midstream part of the value chain being mostly about transport and distribution – land and marine – it was decided to direct the focus of the analysis to the use of EO data in the upstream (exploration, drilling activities and infrastructure development both in-shore and offshore), which seems to be the more defining link in the value chain. Moreover, the investments made in the upstream (exploration and production) directly affects the growth of the midstream and downstream sectors (see figure below for more details). Additionally, this analysis will focus on private end users: the use of EO data by public or non-profit organisations, in public mapping of resources or disaster management.

Taxonomy and definitions

Main definitions related to the O&G value chain	
Exploration	Exploration in the O&G industry refers to the activities performed to monitor large areas and identify potential oil & gas deposits. Surveys, localisation and exploratory drilling are all part of the exploration phase of the O&G upstream industry.
O&G upstream	O&G activities are split between three main components: upstream, midstream and downstream. The upstream includes all the activities related to exploration, construction and maintenance of infrastructure and production & drilling of crude oil and gas.
O&G midstream	O&G activities are split between three main components: upstream, midstream and downstream. The midstream includes all the activities related to the storage, transport and refining of crude oil and gas. Even if pipeline utilisation and maintenance is part of the midstream, the development and construction of pipelines are usually included in the O&G upstream.
O&G downstream	O&G activities are split between three main components: upstream, midstream and downstream. The downstream includes all the activities related to marketing and

	distribution of refined oil and gas products to end users, for commercial and mass consumption purposes.

Value chain description

Generic Oil & Gas supply-chain

Oil and gas are always associated in the same value chain, even if they are two totally distinct energetic products. These two resources are, in most cases, located in the same underground or underwater reservoirs. Both were formed at the same time million years ago when large amounts of dead organisms were left trapped in sedimentary rocks, and were then subjected to intense heat and pressure. This very long process has led to the creation in the same reservoir of petroleum and natural gas released during the decomposition of organic material. These two materials are now the major sources of energetic consumption worldwide.[288]

The O&G supply chain relies on three interconnected main stages, upstream, midstream and downstream activities. The upstream part gathers all activities related to exploration and drilling such as exploitation and appraisal, reserves development and drilling and production. Upstream also involves development activities, which means the construction of the infrastructure to drill the petroleum resources if the reserves are assessed to be interesting enough to be exploited. Midstream activities involve all the transport and storage, through maritime or land transport, from the extraction sites to the refineries. The transformation of crude oil and raw gas into derived products, petrochemicals and consumable oil & gas products is also included in the midstream part of the generic O&G supply chain. The third stage, the downstream part, involves all the marketing, distribution and logistics for the O&G market on commercial and domestic markets. Figure below summarizes the overall value chain.

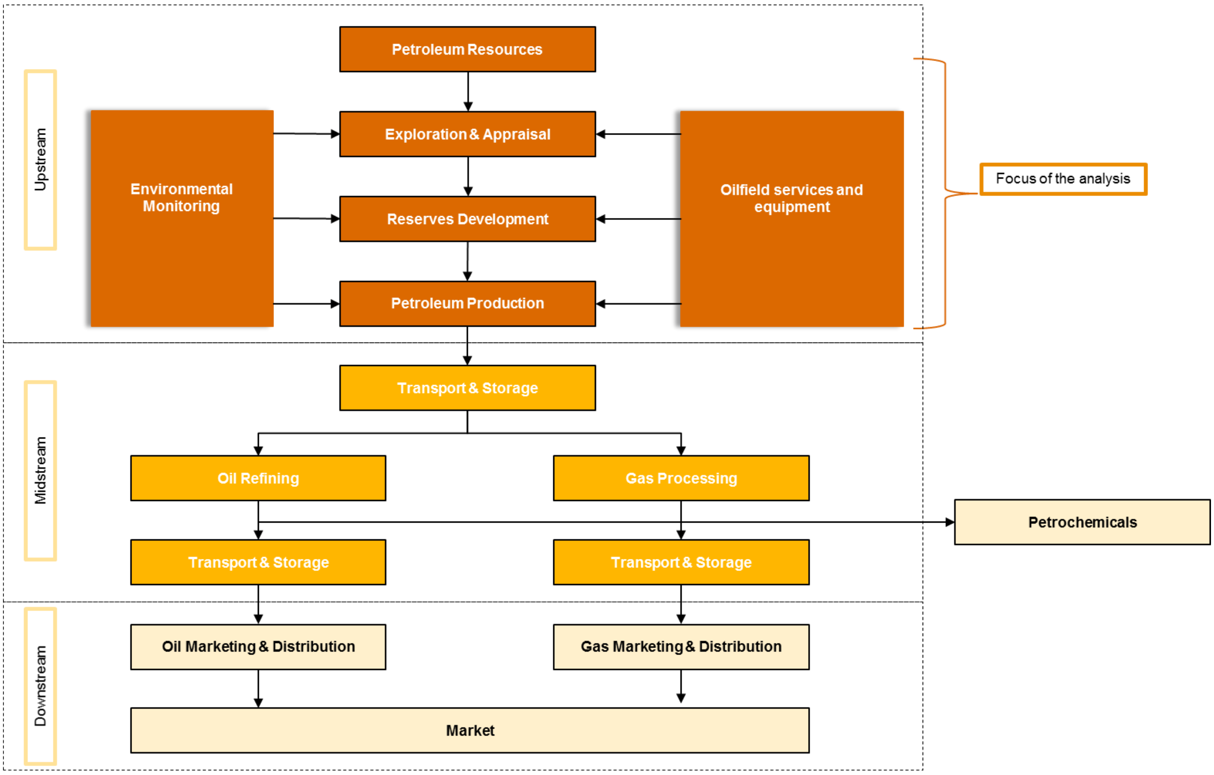


Figure 90 - Generic Oil & Gas supply chain (Source: PwC-Strategy& analysis)

The upstream Oil & Gas industry

The upstream part of the O&G industry is the core of the O&G market. Investments made in the upstream expenditures trickles down in all the other parts of the value chain. More expenses and revenues in the upstream lead to higher growth in the midstream and downstream market since these two ones depend on the flow of O&G extracted and its costs; the opposite is also true, less revenues in the upstream lead to a reduction of activities in the midstream and downstream.

[288] *Shell. Chapter 1: The origins of Oil and Gas in Shell in Alaska. Consulted November, 15 2015. Link: http://www.shell.us/content/dam/shell/static/usa/downloads/alaska/os101-ch1.pdf*

The O&G upstream industry is consolidated, with very large players involved in most of the supply chain and dominating the market.

The following figure presents a characterisation of the upstream part of the O&G supply chain. This part of the supply-chain is split between three main types of activities:

- Main activities are performed by the **operators,** called **the majors.** These large companies are vertically integrated and can be private companies such as BP, Statoil, Shell, Total, etc., or national monopolies such as Petrobras or Pemex. These large actors are able to perform most activities in-house, except for some very specific activities where they rely on oilfield services companies. They are usually fully integrated among the supply chain, from upstream to downstream activities. The world largest operators publicly held are called **super majors**;
- **Oilfield services** include all activities which require very specific and costly expertise or activities performed *una tantum*. For the so-called oilfield services, large actors rely on external companies to perform surveys, build specific oil well equipment & services, oil drilling & services and transportation. The market is dominated by the 5 *oilfield classic* (Schulmberger, Halliburton, National Oilwell Varco, Baker Hughes and Weatherford) sharing one third of the worldwide market, letting the remaining two thirds of the market to a multitude of firms. Most of the actors involved in oilfield services are large companies, even if they are smaller than the majors O&G companies, a part from some very specific remote sensing companies working in the survey area that are very small (between 10 and 50 employees);
- **Environmental monitoring** is nowadays a very important part of the O&G activities. Many regulations were developed all over the world to prevent technological disasters[289] so O&G major actors have to be compliant with these new rules. For this purpose, they usually rely on external companies (consulting firms, remote sensing companies and/or clean technologies providers) to assess and reduce the environmental impact of their activities.

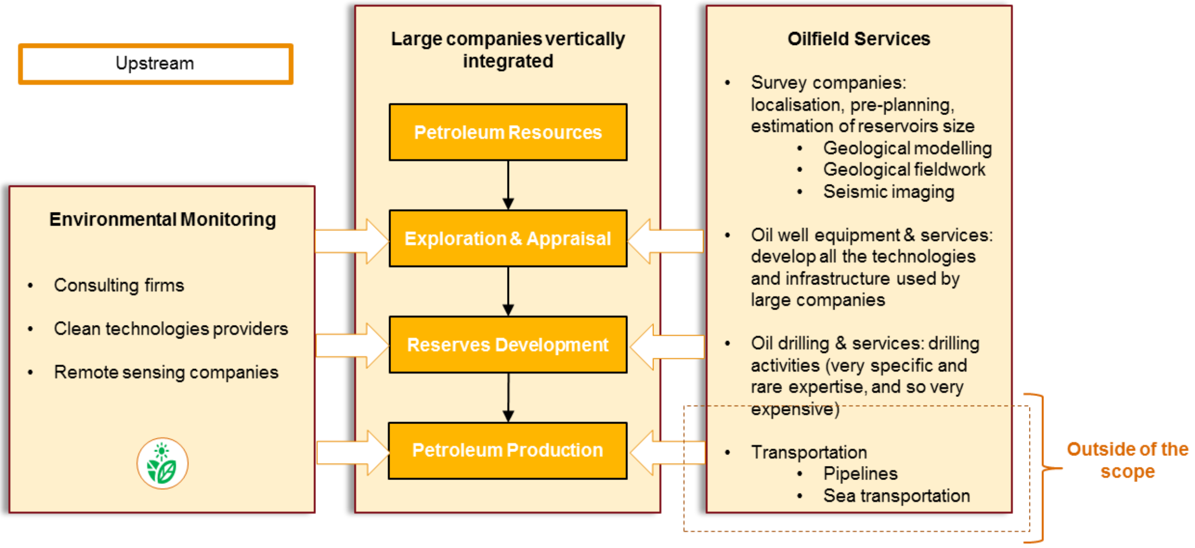


Figure 91 - Characterisation of the O&G upstream supply-chain (Source: PwC-Strategy& analysis)

A distinction between on-shore and off-shore activities can be made in the upstream part of the value chain since crude oil and gas can be both drilled underground (on-shore) or underwater (off-shore); technologies and practices involved vary a lot. The O&G upstream supply chain remains the same for both activities at a very high level of analysis. Once extracted, the value chain is basically the same for on-shore and off-shore activities.

- **Onshore activities** refer to O&G activities performed on land. O&G reserves are usually located several kilometres underground and require specific exploration, drilling, infrastructure development and exploitation activities. Risks of groundwater table contamination are very high during hydraulic fracturing or exploitation of natural gases, because of potential unintentional releasing of toxic gas in underground water. Social responsibility is nowadays more and more important for the O&G industry to mitigate environmental impacts of exploration and exploitation of O&G reserves.

[289] *A technological disaster is, by opposition to natural disaster, a disaster due to human activities such as oil spills, contamination of water or destruction of local ecosystem during exploration process.*

- **Offshore activities** refer to O&G maritime activities. A large share of O&G reserves is located in deep water and need specific activities to be exploited. Exploration, drilling, infrastructure development and exploitation activities are performed very differently compared to regular onshore activities. Weather and sea condition (waves, wind, etc.) induce major risks for offshore infrastructures. In such context, damages to the infrastructure can produce important oil spills leading to tremendously negative impacts for the marine ecosystem and the environment.

The International Association of Oil and Gas Producers (IOGP), formerly OGP, represents the interests of the O&G upstream industry all over the world. Members of the association account for half of the world's oil production and one third of the world's gas production. IOGP aims at sharing best practices among the upstream O&G actors to achieve improvements in security, health, environmental protection and social responsibility. IOGP is promoting safe, responsible and sustainable operations in the industry. IOGP is notably engaged to promote an environmentally responsible Oil & Gas industry. Social responsibility is indeed nowadays more and more important for the O&G industry to mitigate environmental impacts of O&G reserves exploration and exploitation.

The Upstream market function

Major companies are the main players of the O&G upstream industry – they are also the main players of the midstream and downstream industry – and they are clients of all the other services (oilfield services and environmental services). All exploration activities are performed by the operators which buy prospection areas and perform most of the activities in-house. For very specific activities such as exploratory drilling or ex-ante environmental impact monitoring, they rely on outside companies performing oilfield and environmental services. The market is very well organised, very rational and very traditional. Most of the actors are not willing to take too much risk and the industry is strongly cost-oriented. **The main driver of the market is the price of oil**: higher price of the barrel is correlated to higher investments in the upstream and an increase in the drilling activities; the opposite is also true. Investments in new technologies, new methods, or new products – such as products based on Copernicus data – are strongly dependent on the Brent Crude Daily Price – this is the name of the indicator representing the price of oil on the stock exchange market.

Macro-economic context of the O&G upstream industry

Over the last two years, the price decline of the Brent Crude Daily Price was on the same order of magnitude than post financial crisis, losing 72% of its value. In June, 20 2014, the Crude Oil Brent was closing at US$ 114.55/barrel while less than two years later, the price has fallen to US$ 36.14/barrel on January, 1 2016. The figure below gives an overview of the Brent price evolution over the last 10 years, stressing out two periods of strong price decline.

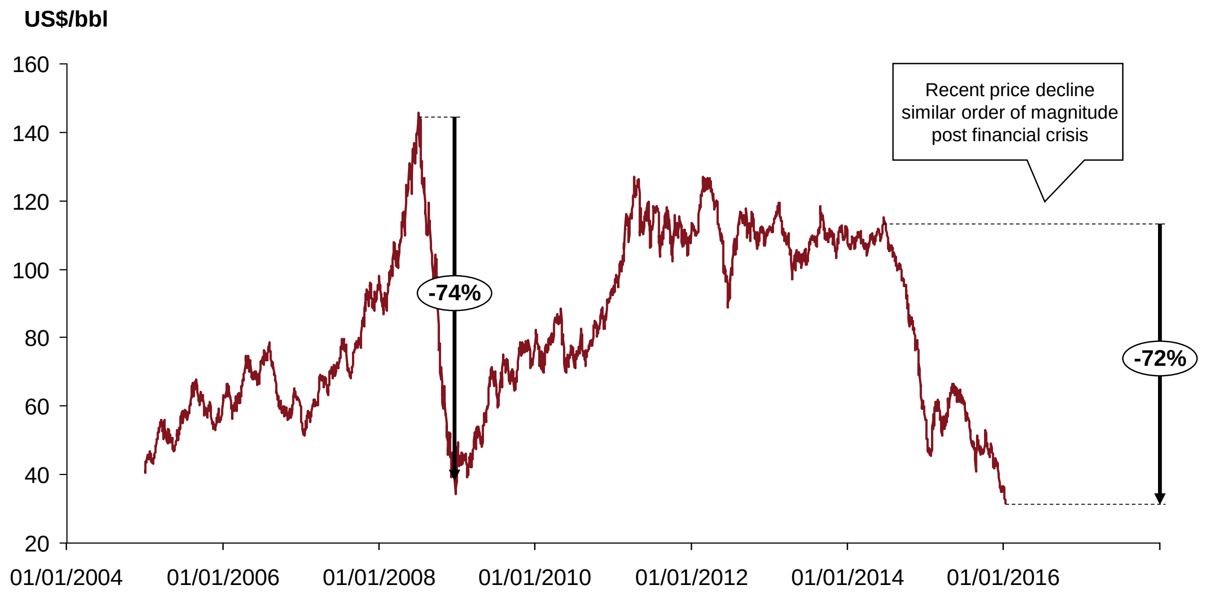


Figure 92: Brent Crude Oil Daily Price on the period January 2005 - January 2016 (Source: Bloomberg, Strategy& Research)

Nowadays, the price of crude oil is still very low compared to summer 2014. The Brent has closed at US$ 48.47 on July, 12 2016. The price of oil is expected to grow in the coming years.

Additionally, the price of crude oil was very volatile over the last months of 2015. Figure 93 gives an overview of the daily difference between high and low price of crude oil over the period January 2001 – January 2016. This volatility increases the risks for major companies and, in an industry where risk is considered as a major threat, investment in exploration are negatively impacted.

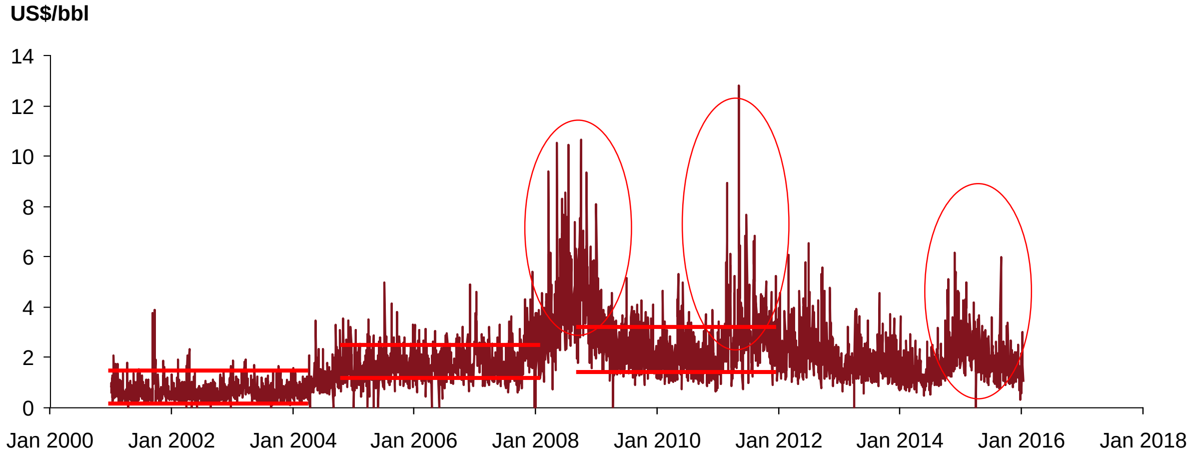


Figure 93: Daily difference between high and low price of crude oil from January 2001 up to January 2016 (Sources: Bloomberg; Strategy& Research)

This important price decline and price volatility are heavily impacting investments made in the O&G upstream worldwide. Operators are expected to cut capital expenditures (CAPEX) by 30% in 2016, leading to postpone or cancel exploration projects for an amount of around US$ 200 B. This pressure related to the price of oil increases the operators' bargaining power on the oilfield services companies, negotiating discount price ranging between 10 and 30%. While the barrel was still above US$ 100 (end of 2014), super majors recorded net income of US$ 22.9 billion while twelve months later, same companies was not recording net incomes. [290] This context negatively impacts the overall revenues of the industry and inhibits investments in new technologies and new practices.

Value chain characterisation from an EO data usage standpoint

Earth Observation has been used among the O&G industry for a long time, through airborne and satellite-based data. The importance of EO data in business models varies extensively from one company to another. For some actors, EO is a tool like many, whereas for others, EO leads to key competitive advantage on the market. Applications related to EO data vary extensively depending on the five main parameters of EO data: spatial resolution, temporal resolution, type of sensors, spectral resolution and archives vs. tasking activities – more details on each of these parameters are available in the introduction of the ***Earth Observation Downstream Market Characterisation*** chapter. In any case, imagery has applications all along the O&G upstream value-chain using different type of resolutions or indirectly using imagery, through the utilisation of larger GIS products. The next section presents briefly how EO data, with a particular focus on Copernicus products, are used along the upstream value chain.

Current use of imagery among the O&G upstream value chain

The main element to understand related to imagery is that EO is a tool among others in the O&G upstream value chain. Each stage of the chain can be performed without satellite-based EO, using for example helicopters, ground teams or boats. EO is both a substitute and a complementary tool depending on the type of applications. As an example, the use of satellite imagery facilitates early exploration to monitor large scale areas that would have been more expensive to monitor using helicopters or ground teams. However, when it comes to verify precisely if the localisation pinpointed using satellites is a real petroleum deposit, ground surveys are mandatory and cannot be substituted by EO data. The following paragraphs will focus more on the use of Copernicus products.

Copernicus products are useful for a large range of applications, from early exploration up to pipeline routing and monitoring. They can be used as a stand-alone product or mixed with data of higher spatial resolution in order to solve complex issues involving many parameters. In a vast majority of the cases, Copernicus products are used by the O&G end-users, especially oilfield services and major companies, among larger GIS products. Figure 94 gives a non-exhaustive overview of how Copernicus products may be used among the O&G upstream value chain.

[290] *Strategy&, 2016. Oil Price Update Q1 2016. January, 2016.*
Link: http://www.strategyand.pwc.com/perspectives/2016-oil-and-gas-trends

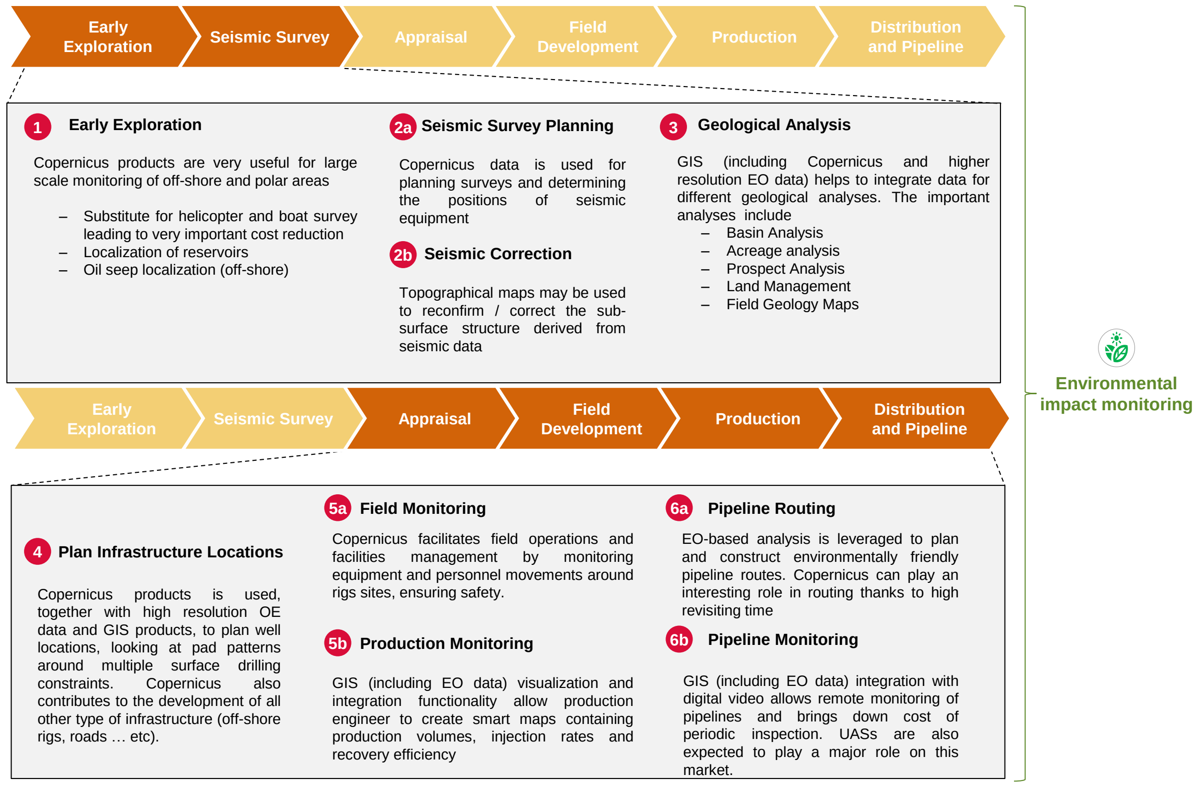


Figure 94 - How Copernicus products are used along the O&G upstream value chain (Sources: expert interviews; Booz&Co., 2014; Strategy& analysis)[291]

Each stage of the O&G upstream value chain has potential applications for Copernicus products:

- **Early Exploration**: this first stage of the value chain relies on the monitoring of specific geographic areas to spot potential positions of petroleum deposits. Sentinels data alone enables the creation of very useful products to monitor large scale area compared to other tools. Copernicus products enable O&G actors to perform large scale prospection on a much more efficient way for both onshore and offshore exploration. Indeed, Copernicus products offer very large coverage that cannot be achieved by helicopter, ground team and/or maritime survey, or at least not at the same cost per squared kilometre. Using satellite data is also way more discrete compared to sending helicopters or boats over specific areas of interest that can be seen by competitors. These products are specifically useful to monitor large off-shore and/or polar areas where companies are tracking oil seeps using radar technologies (Sentinel 1 data). The presence of oil seeps is the mark of the existence of deep-water petroleum reservoirs in 80% of the cases. These early exploration activities can also be performed using helicopters or boats to survey large scale areas, quite often in remote areas, but the price per squared kilometre is way higher than the one related to Copernicus-based products. It is also less risky to use satellites data than boats or helicopters in harsh and remote geographic areas such as polar regions.

- **Seismic Survey:** the second stage of the value chain relies on more advance and precise surveys (compared to early exploration) to analyse the different potential petroleum deposits pinpointed during early exploration. Survey activities are concluded by drilling exploration well to confirm the presence of a petroleum deposit. Copernicus products are very useful to support seismic planning and optimize the positioning of instruments for seismic survey. These products are also used for planning exploration and well construction. The access to an archive of satellites data of the area of interest can also be useful for in-shore survey because it can enable interesting cost reduction. As an example, if a given area is subject to flooding in spring each year over the last 5 years, seismic survey and exploratory drilling will be performed at another period, improving efficiency of survey activities and mitigating the risk of damages to the equipment. Once the seismic survey has been performed, Copernicus products are also useful to calibrate the results and check consistency of some results' parameters.

[291] *Booz&Co., 2014. Geospatial Mapping in Oil & Gas, Upstream and Pipelines. Presentation made in May 2014 by Booz&Co. India.*

- **Appraisal:** if exploration activities were successful – which means a petroleum deposit has been identified – appraisal drilling has to be performed to assess the size and the extent of the reservoir but also the properties of the crude products. In this stage, Copernicus products are used mixed with other sources of imagery of higher spatial resolution and, in most of the cases, the final outputs used by the O&G end-user are GIS products. Indeed, the planning and construction of appraisal drilling are the first step of the development of production capabilities and many parameters need to be assessed to optimize this phase and the next ones.

- **Field Development and Monitoring:** Field development occurs once exploration and appraisal activities were successful to prepare the full-scale production phase. Additional wells are usually drilled and construction of the entire supporting infrastructure (workers' infrastructure, roads, etc.) is performed. Sentinels products are again useful in this phase but they are usually integrated in larger GIS products to optimize drilling activities. However, Sentinel 2-based products are accurate enough to be used alone to plan road construction to access remote on-shore production sites. Fields monitoring activities are related to the facilitation of field activities, insuring security and safety for workers and equipment. This domain is critical for the O&G industry, especially for off-shore and polar activities in remote and harsh areas. Being able to monitor wave height, marine winds, icebergs, ice thickness, etc. is key to protect workers and equipment from natural hazardous. Satellites play a key role to increase safety in such activities. Copernicus products are used to forecast waves and winds and the potential impact on off-shore rigs. However, most of the satellite-based imagery used in field monitoring is related to very high spatial resolution and very high temporal resolution (near-real time).

- **Production:** Once all the above activities have been performed, large-scale production can start, extracting crude oil (and gas) from the field developed. Copernicus products, and imagery of all type of resolution, are used within complex GIS products to analyse and optimize efficiency in production (injection rates, production volumes, etc.). The contribution and potential value of applications based on Copernicus products are very small compared to other value chain's phases. Very high resolution imagery is more likely to be used in production phase.

- **Distribution and Pipeline**: Pipeline and distribution are planned during this phase but these activities are making the bridge between the upstream and the midstream O&G industry. Oilfield services in charge of pipeline routing and monitoring are part of the midstream and even downstream O&G industry. A recent case study was performed by EARSC on the use of Sentinels based product to monitor gas pipeline in the Netherlands and the potential value of such applications is estimated to be between EUR 15.2 Million and EUR 18.3 Million at the scale of The Netherlands.[292] These reasons have motivated the team to exclude Distribution and Pipeline out of the scope.

- **Environmental Monitoring**: environmental monitoring activities have received a more and more important role within the O&G upstream industry. The O&G upstream companies are under scrutiny by NGOs ad public authorities to reduce risks of environmental impacts of O&G exploration activities and technological disasters. Specialized companies, as already stated in the previous section, are performing independently these activities for O&G end-users, monitoring contamination of ground, water (open water, rivers, deep-sea, underground water) and air. It includes three main type of activities: ex-ante risk assessment of exploration activities, environmental surveillance of activities (live) and post-activities environmental impact assessment. EO data are playing a key role in the three type of assessment depending on the spatial and temporal resolution of the satellites used. Live monitoring of activities can be performed at a large scope using Copernicus products, but the largest value is derived from very high resolution imagery. However, for ex-ante and post-activities assessment, Copernicus products can play a significant role to map impact on vegetation, air quality and water contamination. In any case, Copernicus products have to be coupled with higher resolution and in-situ data to perform the overall environmental impact assessment both ex-post and ex-ante.

Market structure and trends

This section focuses on the market trends and dynamics on the EO data usage (market) for the O&G upstream industry. Even if EO data are used in the O&G upstream industry for long time, especially by the geologist community, the usage of satellite-based imagery is still perceived as a new practice for many O&G companies.

[292] *Source: EARSC & The Green Land, 2016. Copernicus Sentinels' Products Economic Value: The case of Pipeline Monitoring in the Netherlands. Report prepared by EARSC and the Green Land under assignment from the European Space Agency.*

The table below summarises the key drivers and barriers for the dissemination of EO data usage among O&G upstream companies.

Key Drivers	Key Obstacles
EO usage is already widely spread in the industry, especially compared to other commercial sectors such as insurance. The geologist **community** relies on the usage of EO data (from airborne and satellite) **for already several decades**.	The **current macroeconomic context of the O&G industry** (collapse of the Brent Crude Oil's price) **does not encourage investments in new practices** and technologies. However, **EO usage is still seen as a new practice** by a lot of O&G companies.
The usage of EO data brings **significant cost reduction and productivity increase** for several O&G upstream activities, especially thanks to the **large coverage offered by satellite imagery compared to other sources of data** (i.e. ground & boat survey, helicopter, etc.). In a very rationale and cost-oriented industry, these benefits should stimulate the dissemination of usage.	Technical information on how to use EO data in the context of specific O&G upstream activities already exist. However, the industry **requires more business proof-of-concept to demonstrate the economic value of the usage of EO data**, and not the feasibility.
EO data being a core component of GIS products, the **fast growing usage** of such product within O&G upstream company should **stimulate the dissemination** of EO data and products.	The type of data required varies a lot from one activity to another: o The **usage of near-real time (NRL) data** is mandatory for some activities but **such data are very costly**. O&G companies **can be reluctant to switch** from current practice (i.e. ground survey or helicopter usage) to satellite-based imagery; o Activities relying on long-time series (i.e. change detection) can be negatively affected by the **non-availability of specific geographic coverage** (no tasking activity available) o by **not long-enough history** (i.e. Copernicus programme).
The **availability of free and open EO data & products should stimulate the usage of EO data and products** such as MODIS, Landsat and Copernicus. Such products give interesting benefits at low cost for O&G companies.	

Table 48 - Synthesis of main key drivers and obstacles related to the O&G upstream industry and the usage of EO data (Source: PwC-Strategy& analysis)

A specific attention is given to the use of internal capabilities (end user) versus the use of intermediate users within this value chain. Two dedicated sections look more in depth to the private imagery market and the GIS market and its new ICT trends impacting the O&G upstream.

Private imagery market for O&G upstream

Based on EARSC data (2015), the European EO downstream industry represents EUR 911 million on which more than 8% are derived from the O&G industry. Based on this amount, the European EO downstream revenues related to O&G should be estimated around EUR 73 million all over Europe[293]. Sales of EO data and related products and services have dropped by 19.24% from 2012 to 2015 while overall sales have increased by 13.72% over the same period.[294] This decline is mainly correlated to the overall macro-economic context of the O&G

[293] *EARSC (2015). A survey into the State AND Health of the European EO Services Industry. Prepared by EARSC under assignment from ESA, September 2015.*

[294] *Commercial EO downstream revenue (based on EARSC, 2015):*

2012: 90.39 million euros

industry already stated in the section before. No figure related to revenues of O&G products and services derived from Copernicus data was found.

(M EUROS)	Overall EO downstream market	% of the overall market for O&G only	EO downstream revenues for O&G
2012	786	11.50%	90.39
2015	911	8%	73

Table 49 - EO downstream revenues in Europe for the O&G industry (Sources: EARSC; PwC-Strategy& analysis)

GIS products and digitalization

The majority of O&G actors mostly use GIS products and services – EO and Copernicus data are already included in such products – and EO only products and services are used in very specific niche markets. 80% of data used by the O&G industry has a geo-spatial component. [295] It is also one the only industry that harnesses its own spatial data in each activity performed along the value chain from upstream up to downstream O&G activities. As already highlighted, satellite based imagery is integrated into large and complex GIS products in most of the cases. GIS products and services play a central role in exploration and production activities (upstream O&G) because they enable a deeper analysis, bringing together intelligence from different domains, including EO. O&G upstream companies are using GIS products to increase their revenues (increase in productivity, cost reduction, etc.), minimizing risks. The fact O&G upstream involves operations dispersed all over the world, managing workers, equipment and infrastructure, so GIS products bring large revenues to O&G companies. However, the geospatial component of the O&G upstream is still underestimated and underutilized.[Erreur ! Signet non défini.] This market presents very promising opportunities for this industry.

More than the value of GIS products in itself, the emergence of the use of GIS within the O&G upstream industry make this industry switching to the platform and cloud paradigm. A dedicated section in the *Earth Observation Downstream Market Characterisation* chapter is explaining this new phenomenon and promising market fo69r EO and GIS. A virtual ecosystem for GIS products and services already exists on which O&G companies can capitalize. Such platforms are game-changer for the industry where the user can easily integrate different sources of data available into web-platforms with its own data – O&G companies have huge repositories of internal data and statistics on all their activities – leading to very high value-added business intelligence for them. These GIS platforms also propose tutorials and trainings on how to apply GIS to specific activities. Some of these tutorials explain how to use imagery, including the use of Landsat and Sentinels data & products. EO data are included in most of these products/services and they bring value in variable proportions; it is very harsh to isolate the real value of EO-data in such products and services. The GIS platform market seems to be very promising and should lead to very large revenues for the GIS industry but especially for the O&G end-users. The platform market includes both the GIS cloud market and the GIS mobile market, as already discussed in previous chapter, and they are respectively accounting in 2015 for US$ 519 M and US$ 523.9 M, expected to grow to US$ 875.9 M and US$ 845.1 M by 2020. Interesting fact, O&G is the main sources of revenues on the GIS cloud market. This trend is a real opportunity for Copernicus products to improve data dissemination and utilisation among O&G end-users.

Looking at the market figures for O&G for Europe, the team has focused on the figure from the GIS data & services market representing 50.5% of the GIS overall market for Europe (excluding GIS software); these figures will then be used as basis for overall assessment of the contribution of Copernicus data and products to the GIS market in Europe. O&G is included in the natural resources' category of GIS revenues. Almost all the revenues derived from the O&G market are derived from the upstream. Based on the International Energy Agency, Oil (32.4%) and Gas (21,4%) represent the largest contributors to the natural resources market, 56.8% of the Natural Resources market. The table below summarises the information related to the estimated size of the GIS sales and services for O&G.

2015: 73 million euros

*((911-786)/911) * 100 = 13.72%*

[295] Source: Deogawanka, S. GIS in Oil and Gas. GIS Lounge. December, 9 2015.

Link: https://www.gislounge.com/gis-in-oil-and-gas/

(M EUROS)	GIS market for Data & Services	Natural Resources	O&G
European market 2015	1 336	171.11	97.19

Table 50: GIS revenues in Europe related to the O&G market (Source: Technavio, 2016)

The leader on the market of GIS platforms for Oil & Gas is the platform Arc GIS, developed and administrated by the US company Esri. The company captures around 80% of the GIS platform sales in the overall O&G industry.[296] More details on Arc GIS and Esri are available in the *Earth Observation Downstream Market Characterisation* chapter.

Data flow along the value chain

This section aims to summarise how value is created among the EO value chain within the O&G upstream industry. Copernicus data and products follow exactly the same scheme of data flow than any other EO data; this is way this section is not specific to Copernicus data and products but EO in general.

Internal capabilities and use of intermediate users

The use of imagery within the O&G upstream industry varies a lot from one actor to another. Some O&G end-users use EO based products created through their own EO in-house capabilities, others are buying products from intermediate users while others do not use EO at all. There is no common pattern within the industry on how imagery is used by end-users. As stated in the previous section, **EO is tool among many and each stage of the O&G upstream value chain can be performed without using imagery**. O&G end-users are often skeptical on the real value-added derived from satellites data compared to "traditional approach" (helicopters, ground teams and boat surveys), especially because implementing such practices when they do not have in-house capabilities and knowledge requires development of new expertise and new practices. Such implementation, even if it should lead to important cost reduction in the mid-term, requires investment in the short term. Current macro-economic context does not stimulate the willingness-to-invest of major companies in new products, such as Copernicus based ones, and the O&G industry is by nature very traditional and slow to implement new practices and new technologies. However, on the sample of firms interviewed (7 O&G upstream end-users), all the companies that do not have any in-house EO capabilities have already started or plan to build such capacity in the coming years. Indeed, **100% of the O&G upstream end-users engage in direct consultation have manifested a strong interest in EO-based products, especially in the free and open Copernicus products.** This strong interest in EO and Copernicus data should positively impact the penetration rate of Copernicus products within O&G upstream end-users over the coming years (5-10 years), if the Crude Oil Brent grow up again and if the access to data is made more user friendly,

In general, the use of EO data follows the golden rule in the O&G industry: if a given activity is performed only sporadically, it is usually outsourced to a third party, here an intermediate user; if not, it is performed in-house following a cost-benefit approach. In general, the basic EO activities will be processed through internal capabilities and specific expertise and tasking activities will be performed outside of the company. Despite the fact some O&G upstream end-users have their own in-house activities; this does not mean that they are not using products or services from intermediate users for very specific activities. A part from very few companies with strong EO expertise, more and more O&G end-users are interested by already-processed EO-based products (higher than an EO level processing of L2) they can integrate into larger GIS products to create business intelligence tailored for the specific needs of the end-user. Some in-house capabilities are still required to perform this last stage of analysis, but way less than if the full processing activities have to be performed from level 0 up to L4.

The role of Copernicus core services within O&G end-users

Identifying the role of each Copernicus core services was not possible in the case of the O&G upstream value chain. Apart from very specific companies, O&G end-users do not access directly to Copernicus products using the Copernicus core services. The only exception will be for all the off-shore O&G activities, most of the companies interviewed already used models and products accessed through Mercator Ocean, in charge of Copernicus Marine core service. Products related to the current stage and forecast of the conditions of the ocean are very useful for such type of O&G exploration and production activities, especially for safety reasons.

[296] *Source: Expert interviews; Booz&Co., 2014. Geospatial Mapping in Oil & Gas, Upstream and Pipelines. Presentation made in May 2014 by Booz&Co. India.)*

The environmental dimension of the six Copernicus core services makes a lot of the products not directly of interest for O&G end-users. Such products represent interesting opportunities for environmental monitoring firm to calibrate their own results. However, activities performed by such type of actors required very local data to perform accurate environmental assessment. The companies interviewed for this study were developing in-house products based on Sentinels data or very specific areas of interest.

Conclusion of data flow along the O&G upstream value chain

Erreur ! Source du renvoi introuvable. summarises the data flow among the O&G upstream value chain based on EO data. The chart presents here at a very high level how EO raw and quasi-raw data are transformed into business intelligence applied to a very specific O&G upstream activity. If this chart aims to represent how the value is created for the end user into the O&G upstream value chain, this does not mean all the actors are using all the activities presented here. Depending on the type and size of companies but also the stage of the O&G upstream value chain and type of environment being prospected (on-shore, off-shore, polar), the usage of EO data varies extensively.

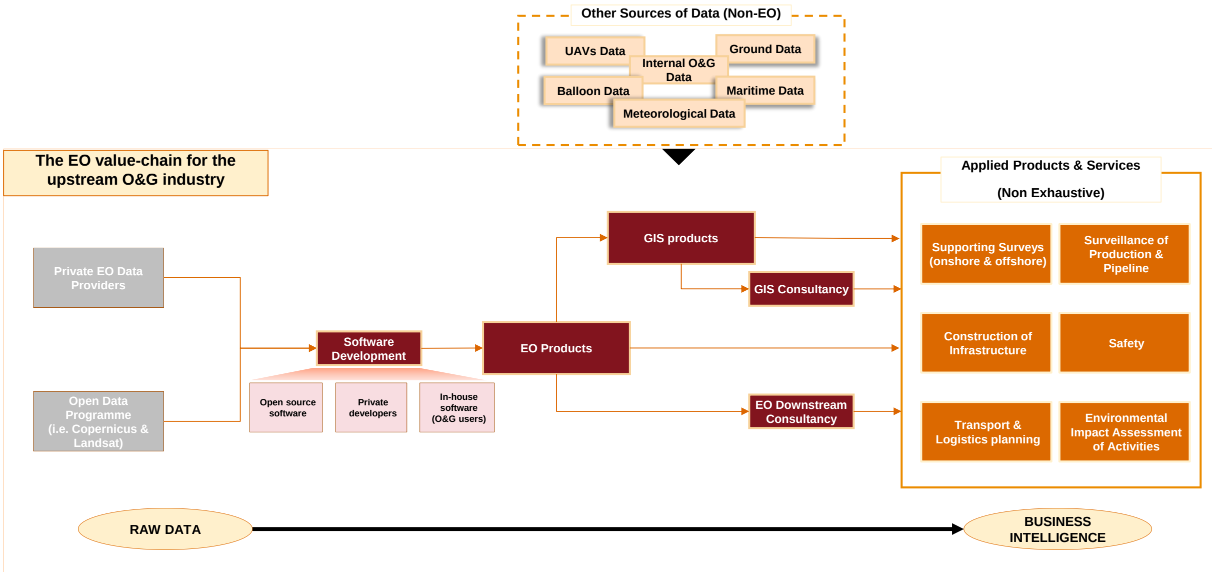


Figure 95 - EO value chain for the upstream O&G analysis (Source: PwC-Strategy& analysis)

The EO value chain has two main components for raw data and quasi raw data: the private and free & open sources of data. Both types of data use the same format (international standard), which facilitates their integration into specific software to increase the processing level of the data. Different types of software are used in the O&G upstream industry:

- **Open source software**: software free of charge, such as the one used to develop Copernicus core services products, that can be easily found on Internet. Programmes such as Landsat and Copernicus use the crowdsourcing platform GitHub to disseminate the software developed. The outputs of such software usually offer generic solution and not very advanced products. However, some software used by the scientific community can be quite advanced;
- **Private software**: software based on licence and/or utilisation fees that are developed by the EO downstream industry or the GIS industry. The outputs are usually very specific and advanced, bringing important value-added for the users which justifies the fee.
- **In-house software**: some O&G end users with strong internal EO capabilities develop their own software for their specific needs. Such software is usually linked to stronger GIS software to support the integration of large volume of data and statistics.

Whatever the software used, the outputs are the same: an EO product use to support O&G upstream activities. O&G end-users use EO-based product in three different ways:

- **As a stand-alone product processed internally** for recurrent activities performed by the O&G company;
- **As a stand-alone product bought from intermediate users** for very specific activities too costly to be performed internally and requiring advanced specific expertise in EO;
- **As a product integrated into a larger GIS product** together with many other sources data, leading to very advanced and complex products; O&G end-users use imagery in this way in the vast majority

of the cases. The stand-alone EO products (developed internally or bought to third party) are quite often also integrated into larger GIS products once they have been used for a specific application such as large off-shore area monitoring for potential O&G deposit identification.

The development of a product and/or service/consultancy, whatever if it comes from internal or external sources, applied for a very specific activity, such as environmental impact assessment of off-shore drilling or supporting on-shore appraisal activities, lead to the creation of business intelligence for the end user. This business intelligence can then be transformed into increase of revenues, cost reduction or productivity increase.

Copernicus socio-economic impact assessment

This section focuses on the monetary impact assessment of the use of Copernicus data and products in the O&G upstream industry in Europe. The socio-economic impact of the Copernicus programme has been assessed using a case study approach, that has then been extrapolated to the overall O&G upstream industry in Europe.

The Earth Observation for Oil & Gas (EO4OG) project was chosen as case study because it is one of the most comprehensive initiatives led in Europe on the dissemination of EO data into the O&G upstream industry. This initiative does not focus explicitly on the Copernicus programme but on the use of EO data in general within the O&G upstream industry. This initiative has amongst other led to the creation of a subcommittee within the IOGP dedicated only to EO dissemination within the O&G industry. More recently, a new initiative funded by ESA, the Energy broker platform, follows the EO4OG's recommendations to foster the use of EO data, developing a broker platform to link end-users and intermediate users within the O&G.

The EO4OG case study is also a strategic choice in terms of socio-economic assessment because it offers access to relevant and representative sample of all the different type of companies included in the O&G upstream value-chain: major companies, oilfield services, environmental companies and intermediate users (EO downstream and GIS). Such case study also enables the team to access to users or companies interested in using EO data, which means potential users of Sentinels-based products. Companies in the sample were from Europe and Canada; the results per type of actors from the case study were then extrapolated to the overall upstream O&G market for Europe only (not for Canada).

CASE STUDY

The EO4OG project

Presentation of the EO4OG project

The use of EO data in the O&G industry in Europe increased significantly over the last couples of years. This increase was supported by several initiatives that have facilitated the dissemination of EO data in daily O&G activities; the Earth Observation for Oil & Gas (EO4OG) project was one of them.

ESA, EARSC and IOGP have recently developed new collaborations to bring together EO and O&G communities. The aim of such initiatives is to solve new challenges faced by the Oil & Gas industry, in particular moving exploration in high latitudes (i.e. Arctic exploration activities). Social responsibility is nowadays a major concern for the O&G industry. These new collaborations aim at developing partnerships between EO experts and O&G experts to stimulate the use of Copernicus data. The Oil and Gas Earth Observation group (OGEO) was founded in 2010 after the First Oil and Gas workshop organised by ESA in ESRIN, Frascati, Italy. During this event, the O&G community representatives raised specific issues faced by the industry. EO experts then assessed if some EO products or services could be developed to solve O&G problems. This event has led to the build-up of an OGEO web-portal hosted by EARSC, where members of both communities can exchange best practices and issues to be solved.[297] Learning about OGEO, the IOGP has decided to capitalize on the existence of this group and integrate it into its activities as a formal subcommittee which aims at fostering the use of EO data in the O&G industry. Many internal discussions were pointing to the fact that it should be important to carefully map O&G industry needs and challenges to support the EO downstream market. The EO4OG project is born following these discussions: ESA has initiated the project with originally two projects. ESA has received more than 30 consortiums responses to the tender, they have decided to fund four projects – two on-shore and two off-shore – in order to support market development. The results of these four two-year projects were a very comprehensive list of products European EO downstream actors should work on to respond to the challenges faced by the O&G industry. More details on the type of products are provided in the Appendix.

Results of the project

The results were very well received by the industry and it has largely contributed to raise awareness on the interest of using EO in O&G activities. However, the results were released in June 2014. As shown in Figure 96, the macro-economic context for the O&G industry since the end of the EO4OG project is not positive with the price of oil declining on the similar order of magnitude than post financial crisis, losing 72% of its value in two years.

[297] *OGEO platform website, consulted November, 12 2015.*
Link: http://www.ogeo-portal.eu/

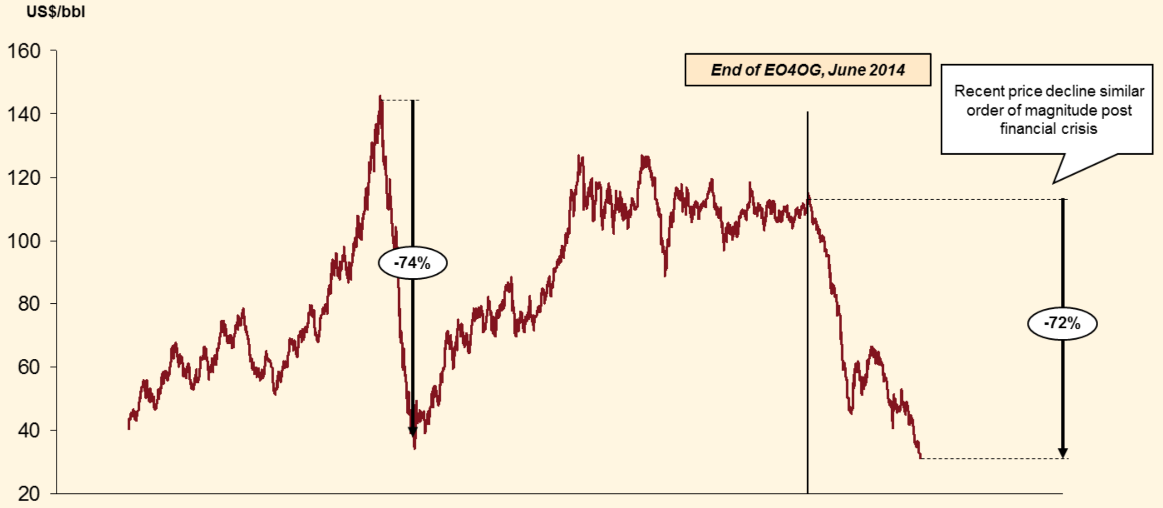


Figure 96 - Brent crude daily price, January 2005 - January 2016 (Sources: Bloomberg; PwC-Strategy& analysis)

As highlighted earlier, the O&G industry is led by the price of oil: when price is low, the industry drastically reduces its investments in exploration and drilling. This context has very negatively affected the penetration rate of EO products in the O&G industry, including the ones using Copernicus data. More details on the macro-economic context of the O&G industry can be found the "O&G Value chain description". However, all O&G actors interviewed for this study have highlighted the fact that they are very interested in EO products produced internally or bought to EO downstream actors. The main hindrance to EO for O&G market expansion comes from the clients who are not willing to buy new products considering such a low price of oil.

Quantification of the contribution of Copernicus data & products

The quantification was done on a sample of 12 European and Canadian firms, including operators, oilfield services companies and EO downstream actors, from various geographic areas (UK, France, Norway, Italy, Austria, the Netherlands and Canada). Companies that were unable to derive a real value related to Copernicus data where not quantified (contribution of Copernicus data and products = 0%) to be conservative and avoid using random proxy figures (i.e. 1 or 3%), especially in the context of an industry with very large revenues (more than EUR 479 billion in 2015 in Europe).[298]

The first statement is that it is still very early to properly assess all the revenues enabled by the Copernicus data and Copernicus core services products. Given this statement, revenues enabled by the availability of Copernicus data might seem small but the methodology used aims at showing the existence of a phenomenon rather than assessing the exact value. The methodology uses a very conservative approach and it offers a minimal estimation of the effect. However, 100% of actors are very interested in Copernicus data and products but, because of the macro-economic context of the O&G industry and the issues faced by most of the actors to access the data, a lot of them are not deriving revenues from Copernicus data and products yet. 44% of the firms do not have any revenue related to Copernicus even if they are positive on the fact that they can derive interesting revenues in a near future (5 years) if the macro-economic context and the data access are improved. The table below summarises all the minimal proven revenues enabled by the availability of Copernicus data in the sample under scrutiny. The total enabled revenues linked to Copernicus only reach at least EUR 8.75 million (minimal estimation).

	Total value of enabled revenues (M euros)	Proportion of total enabled revenues (%)
Total market effect	**7.98**	**91.20%**
Increased sales of existing products	5.36	61.26%
Increased sales of new products on existing market	2.62	29.94%
Creation of a new market	0	0.00%
Total commercial effect	**0.70**	**8.00%**

[298] *Source: Bloomberg, consulted on 04-03-2016*

New networks and partnerships developed thanks to the Copernicus programme	0.70	8.00%
International collaborations	0	0.00%
Total organisational effect	**0.07**	**0.80%**
Improved production methods	0	0.00%
Improved efficiency/productivity	0.07	0.80%
Total enabled revenues (M euros)	**8.75**	**100.00%**

Table 51 - Overall revenues by the availability of Copernicus data within the EO4OG project (Source: PwC-Strategy& analysis)

The chart below gives a visual overview of the repartition of effect and how the enabled revenues are split between the types of actors. Most of the enabled revenues are due to market effect (91%) which means the availability of Copernicus data enables a better offer for these companies in terms of increased sales of existing products and increased sales of new products on existing market. For 8% of the enabled revenues, the availability of Copernicus data has led to the creation of new networks and partnerships that have benefited to revenues.

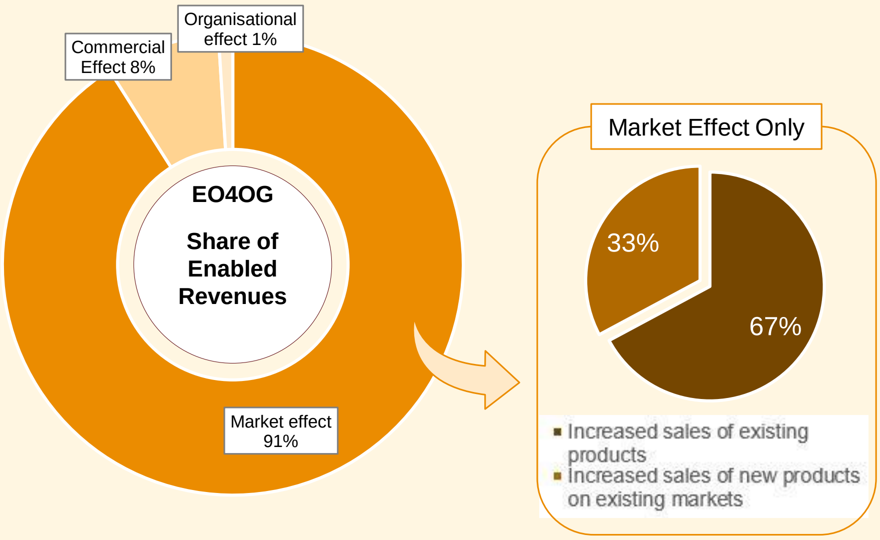


Figure 97 - Enabled revenues by the Copernicus data: repartition of effect in the sample under scrutiny (Source: PwC-Strategy& analysis)

Figure 97 gives an overview of the repartition of the market effect. In 67% of the cases, the availability of Copernicus data and products has led to increase sales on existing market. The 33% remaining has led to creation of new products on existing market. The fact commercial effect and organisational effect are very low compared to market effect can be explained by the fact Copernicus data and products are available only since one or two years (Sentinel 1 and 2). Such type of effects requires more time to be developed, through the development of new partnerships/collaboration or the implementation of new practices. We can expect having higher commercial and organisational effect in a five-year horizon.

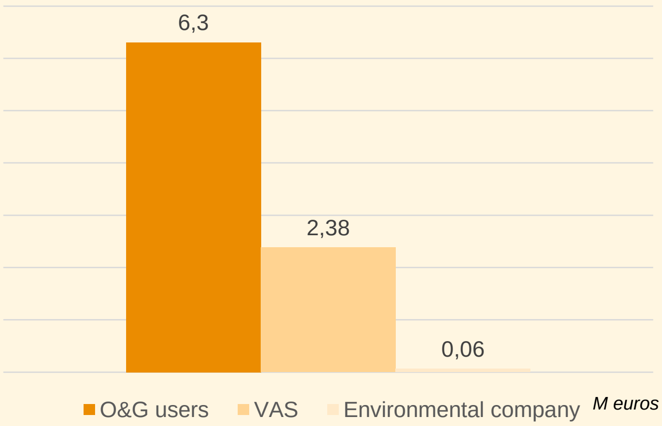


Figure 98: Repartition of enabled revenues per category of companies in the sample under scrutiny (Source: PwC-Strategy& analysis)

Figure 98 illustrates the repartition of benefits per type of users: environmental firms, intermediate users and O&G end-users. Note that oilfield services and major companies have been aggregated in the broader category *O&G end-users* to ensure anonymity. A very interesting fact is **72% of the benefits enabled by the availability of Copernicus data ad products are derived from O&G users, and not from the intermediate users**. This finding is very interesting because all the socio-economic assessment studies analysed during the literature review were focusing of the revenues derived from sales of private intermediate users, and not looking at the value created by end-users' usage. However, the stakeholder consultation has demonstrated the value created by the Copernicus programme in the O&G upstream value chain brings way more value for end-users than for intermediate users, in the case of our sample in a ratio of more than 2.5.

The next section illustrates a new initiative led by ESA to foster the use and dissemination of EO data in the O&G industry (not upstream only). The Earth Observation Broker Energy platform follows several recommendations made in the EO4OG project.

The Earth Observation Broker Energy platform

The Earth Observation broker Energy platform, also called energy Broker platform, is a communication device which aims at bridging the O&G industry and EO suppliers on a web-based platform. The platform is a proof-of-concept one-off project developed by a consortium of 5 European organisations (Geocento, Kongsberg Satellite Services, Satellite Application Catapult, EO Map and Globesar) and the platform will then be owned and operated by ESA, bearing all costs related to the maintenance and upgrade of the platform. The Earth Observation broker Energy is a two-year project funded by ESA and it is built on the recommendations and lessons learnt from the EO4OG initiative. With this initiative, ESA wants to position itself as the cornerstone of the European EO ecosystem to support market growth. The aim is to give the spark, through public investment, that will motivate private investments into the ecosystem.

The role of such platform is to bridge two community and foster the dissemination of the EO data into the O&G industry. Even if the platform was originally designed for O&G actors, the vision of ESA is to extent it to more sectors, pushing for the development of a cross-fertilisation platforms. The platform was designed to make offer and demand meeting on the web-based space, boosting the volume of commercial transactions between EO and OG communities. The Energy platform is a broker connecting two communities so it will not offer any transaction on the platform. Once a relationship is established between the EO and O&G organisations, transactions will occur outside of the platform through regular distribution channel or third party platforms. ESA will bear all the cost related to the platform but the agency plans to let the platform open and free-of-charge for everyone, pushing the access in a medium term the platform to more than the O&G community. Even if the focus of the initiative is to foster European economy growth, no geographic restriction is applied to the Energy broker platform. They will be first providing private EO actors products and services but ESA also aims at providing Sentinels data, Copernicus products (involving more than only Sentinel data), UAVs products and all other type of data. ESA is starting this initiative with the O&G sector but they plan to rapidly expand to all other industries, pledging for a cross-sectoral approach. EARSC will be at the heart of the ecosystem to facilitate collaborations between EO downstream actors, with a particular focus on the European industry, and private end users.

How is the platform working? Two options are currently under scrutiny: an unstructured and a structured approach. The first one is based on a universal search text box (Google-like search engine) where the user types key words based on O&G ontologies and he has then access to the content of the platform. The second option is based on a structured access meaning the search engine will be structured by thematic, geographic area, type of environment, job role, technology… etc. In both options, the user can type whatever is looking for and the natural language processor will translate everything into existing products and services responding to the criterion asked by the user.

The platform's content is organized in two part:

- The first part provides the users with all the information related to the products/services of interest. This part aims at providing generic and public information related to a selected product/service in a specific context (thematic, geographic area… etc.) for non-technical users such as:

- Video-capsules on how the product/service works
- Case studies;
- Current projects using the product/service;
- Guidelines, standard or references;
- List of suppliers.

If someone is new in the business, this part of the platform will offer him the basic knowledge on how to use EO data in a very specific context. If the person is an expert, the first part can be skipped and go directly on the second part.

- The second part aims at assessing feasibility of the user request. This tool provides the user with all the statistics and information needed to understand if EO can be useful or interesting for its particular problematics providing him with:
    - Cloud statistic;
    - Forecast;
    - Amount of data available in the archives;
    - Geographic repartition of data;
    - Best revisiting time available (temporal resolution);
    - Potential for new acquisition (tasking options);
    - Licensing terms to use the data;
    - Budget required to proceed a specific analysis.

This type of platform is complementary to cloud based processing already existing on the market. It enables a better bridge between non expert community – here the O&G community but it is planned to be enlarge to other communities – and the EO downstream suppliers. Once a product is spotted by a user, the Energy broker platform can redirect him in direction of specific cloud-based platform owned by third party. The final product should be presented at the end of 2016 at an international O&G workshop to explain how is the platform working and demonstrate potential benefits derived from the use of such platforms for O&G actors.

Copernicus current and prospective enabled revenues for intermediate and end users

This section aims to extrapolate the results from the case study to the overall population under scrutiny, the O&G upstream market in Europe. The current revenues enabled by the availability of Copernicus data seem to be low in the case study. However, several points have to be raised:

- **Scenarios approach**: two scenarios were analysed: a minimal estimation and an optimistic scenario. The first scenario relies only on the case study analysed, and the twelve companies interviewed. The methodology aims to provide a minimal estimation of the revenues enabled by the availability of Copernicus data & products to show the existence of a phenomenon rather than assessing the exact value. The exact value is by nature almost impossible to assess on a large scale. Programme such as Copernicus. The optimistic scenario extrapolates the results from the minimal estimation using macroeconomic indicators of the European O&G upstream industry. More details are available later in this section;
- **Users uptake**: the Copernicus data and products are available only since respectively one and two years for Sentinel 2 and Sentinel 1. As highlighted in the "**Theoretical predictions**" section, users' uptake for the Copernicus programme is expected to range between 0 and 2 years because time is required to develop new products based on a new source of data. **Such context negatively impacts the current enabled revenues derived from Copernicus data & products but expectations on the prospective revenues are very positive**. Indeed, **several intermediate users and O&G end-users interviewed have are already developing products based on Sentinel 1 and 2** (stand-alone product; product mixed with higher resolution data; product integrated into GIS products); they do not have any revenues yet related to these products;
- **O&G macro-economic context**: the **macro-economic context of the O&G industry**, as already explained earlier, **<u>does not stimulate investment in new technologies and new practices</u>**, negatively impacting the dissemination of Copernicus data and products. All these elements explain also why the overall enabled revenues are very low in 2015 compared to 2020.

Figure 99 illustrates the current and prospective revenues enabled by the availability of Copernicus data for the upstream O&G industry in Europe. The calculations were performed using the approach explained in the

"Methodology" section, extrapolating the results from the case study to the overall population under scrutiny, the European O&G upstream industry. It includes the revenues enabled for O&G end-users (majors and oilfield services companies) and intermediate users (EO downstream and GIS companies in Europe). Unfortunately, **no figure was identified relative to the environmental monitoring companies even if the <u>market is expected to offer interesting business opportunities in the coming years</u>; in order to be conservative, <u>such type of actors were not included in the calculations</u>.** The choice was made, in accordance with stakeholders' willingness, to not present the benefits per O&G upstream activities (early-exploration, appraisal, field development, etc.) for sensitivity reasons.

The minimal estimation curve (dark blue) represents the sample under scrutiny in the case study (n = 12 companies). The optimistic scenario, as stated earlier, represents the expected benefits for the overall European O&G upstream market. All the figures used to assess the overall market related to the O&G users (European O&G upstream industry) are based on Bloomberg, Rystad Energy and public documents (O&G companies' annual statements, industry surveys, etc.). The figures related to the use of EO data and Copernicus per type of actors are based on stakeholder consultation, derived from the case study (EO4OG project). More details on the following figures and calculations performed can be found in the Appendix.

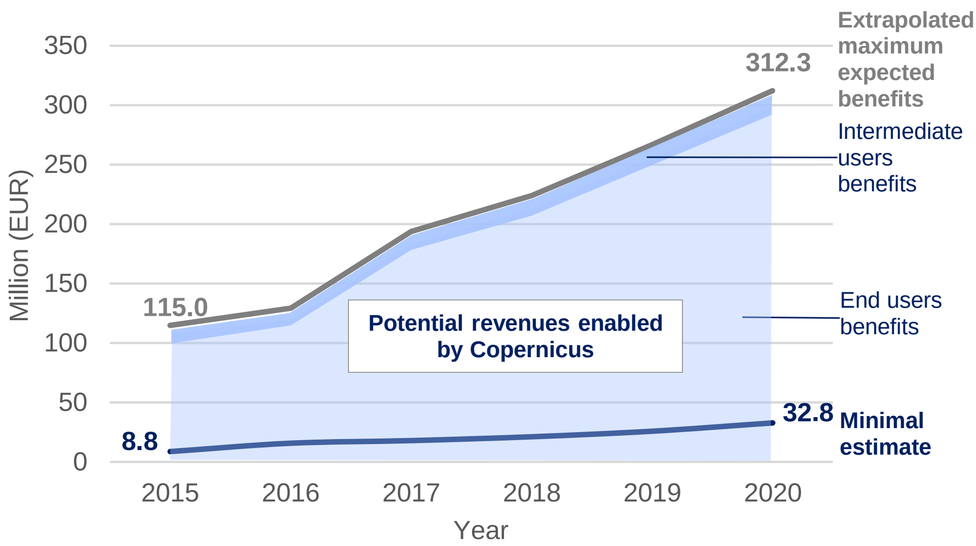


Figure 99 - Current and prospective enabled revenues by the availability of Copernicus data in Europe (Sources: experts consultation; PwC-Strategy& analysis)

The minimal estimation scenario in 2015 is equal to EUR 8.75 Million, expected to rise to EUR 32.83 Million by 2020. The overall market estimation scenario is estimated at EUR 114.96 Million in 2015 and it is expected to grow up to EUR 312.26 Million by 2020. As stated in the *"Methodology"* section, the reader should be focusing <u>on the minimal estimation trends to have access to the conservative and more robust figures</u>. The first goal of micro-diffusion model is to show the existence of the phenomenon rather than give the exact value of the enabled revenues by the Copernicus data. Note that the minimal estimation trend is only based on the enabled revenues within the sample under scrutiny so the real value of the market for Copernicus data (all O&G upstream companies all over Europe) is likely to be higher than the minimal estimation.

Looking at the repartition of the enabled revenues, most of the revenues are surprisingly derived from the end users and not from intermediate users. The two scenarios (the minimal estimation and optimistic scenario) highlight a very large proportion of end user benefits:

- 2015: 72.69% - 88.16% (minimal estimate – optimistic scenario)
- 2020: 72% - 92.55% (minimal estimate – optimistic scenario)

The table below gives more detailed on the repartition of the revenues between intermediate and end users.

(M EUR)	Enabled revenues for <u>intermediate users</u>	Enabled revenues for <u>end users</u>	Total
2015	2.39 – 13.62	6.36 – 101.38	8.75 – 115
2020	9.24 – 23.23	23.76 – 288.77	33 – 312

Table 52: Summary of the the European O&G upstream industry enabled revenues by Copernicus data & products for intermediate and end users (Source: PwC – Strategy& analysis)

Several potential limitations have to be raised. The size of the sample under scrutiny in the case study (n=12) compared to the size of the Oil & Gas upstream – more than 200 companies of all sizes – makes the sample not fully representative.[299] This last comment also explains why the minimal estimation is small compared to the overall estimation. Another potential limit is the fact that O&G users included in the sample under scrutiny are more likely to use EO and Copernicus data compared to other O&G upstream companies, since they were involved in a project with ESA. On another hand, the O&G industry being very competitive and having a strong inclination to keep track of the competition, we can easily estimate that large companies on this market should use similar approaches and tools.

Over the period 2015 – 2020, Copernicus-enabled revenues in the Oil & Gas value chain are forecasted to support a total estimated **between 300 and 1400 person years** in Europe. Most of the supported jobs are within the EO downstream market with between 260 and 830 person years.

It is assumed that productivity among the end users in the oil and gas sector was the same as for the industry NACE 06 and that productivity among the intermediate users was the same as for the industries NACE 62.01 and 62.02. The enabled employment estimation method used employment, turnover and GVA data from the Eurostat Structural business statistics. The 2020 estimates were based on E3ME growth projections for these variables.

Figure 99 offers an interesting vision on the current and prospective value created by Copernicus data & products over the next 5-10 years. An important difference can be seen between 2015 and 2020 in the overall market. This strong increase in market value is mainly due to the expected penetration rate of Copernicus data and products which is currently very low among majors and oilfield services companies. However, both types of actors are very interested by such data and stakeholder consultation shows interesting expected growth of revenues derived from Copernicus data and products for such companies. This estimation is also correlated to an expected growing price of oil in the coming years. The fact the O&G upstream industry (end-users) are more and more relying on GIS products have also played a role on the estimation of penetration rate and forecasted enabled revenues by Copernicus since all the GIS companies interviewed are currently finalizing several GIS products for the O&G upstream industry and other industries) which include Copernicus data & products.

[299] *A sample is generally considered representative when it gathers at least 30% of the observation, insuring representativeness in terms of size of companies, type of companies and geographic repartition.*

Voice of Copernicus users[300]: SWOT

STRENGHTS

- EO data is already widely spread in the O&G upstream industry, which should facilitate the dissemination of Copernicus data and products since most of the O&G actors have their own in-house activities.
- Copernicus data/products are not substitutes of the tools currently used in the O&G upstream industry. Copernicus data are complementary to other tools, including UAVs data. Copernicus provides medium and high resolution of large areas whereas UAVs provide very high resolution data of very local areas.

OPPORTUNITIES

- Interesting initiatives, such as the *Energy broker platform* developed by ESA should foster the use of EO data, including Copernicus data and products within the O&G industry, in the coming years.
- GIS products are already widely used in the O&G upstream industry. The more Copernicus programme will collaborate with GIS providers, the more Copernicus data/products will be used.
- Availability of large archives of Copernicus data should stimulate the utilisation of data over the coming years.

WEAKNESSES

- O&G exploration activities are usually performed in very remote and isolated areas. Many actors have pinpointed the fact that currently not enough archives are available. This will come with the continuity of the Copernicus programme.
- Copernicus data has to be coupled with other types of data (very high resolution data and in-situ data) to solve O&G upstream issues.

THREATS

- The O&G industry is very dependent of its macroeconomic context and the price of oil.
- Data access has to be improved to properly foster the dissemination of Copernicus data and products.
- Non-technical actors related to EO need more materials (trainings, guidelines, etc.) to be able to pick up the use of Copernicus data and products within their own products.

[300] *PwC-STRATEGY& analysis, on the basis of interviews conducted in 2016 (cf detailed list of interviewees in the appendices)*

Policy recommendations to foster the use of Copernicus data and products among the O&G upstream industry

Strategic pillar	Sectoral recommendations for policy action	Priority level
Pillar I: Ensure access to data	**#OG-1 - Create more bridges between the Copernicus programme and the GIS virtual ecosystem** O&G end users are integrating EO products into their GIS products. The Copernicus programme should continue pushing for the integration of the Sentinels data and products into the virtual GIS ecosystem such as the private platforms Arc GIS (Esri), Hexagon Geospatial (Hexagon AB), Geospatial Big Data Platform (Digital Globe) or Google Earth Engine (Google) for examples. Providing on these platforms tutorials and video capsules on why and how integrate Copernicus data & products into GIS products for specific O&G upstream activities can contribute strongly to Copernicus data dissemination.	1
Pillar I: Ensure access to data	**#OG-2 - Push for the development of more guidelines, trainings and white papers specifically designed for O&G exploration activities** Beyond the physical access (via data warehouse or specific platforms), many O&G actors pinpointed the technicality as a barrier to access Copernicus data. More specific guidelines, trainings and white papers on how to use Copernicus data and products in very specific O&G exploration or production activities are required. Tailored training on how to integrate Copernicus data with other sources of data should also contribute to facilitate non-EO experts to access, use and create value using Copernicus data and products.	2
Pillar II: Support innovation	**#OG-3 - Increase collaborations between government, universities and the private industry** Collaborations between universities and the private industry should be encouraged. Government can play this role of bridging those two worlds where universities are able to provide pre-commercial proof-of-concepts of usage of Copernicus data applied to specific O&G activities (publications, potential royalties). Industry is then able to push the concept to the market and derive revenues from it, using the products in their commercial activities.	2
Pillar III: Increase awareness	**#OG-4 - Develop economic/business proof-of-concepts** Many technical proof-of-concepts already exist for the use of EO data in the O&G upstream industry. To foster the dissemination of Copernicus data within the industry, organisations currently need proof-of-concepts on the business and economic side to demonstrate the type of cost reduction or gain in time and productivity enabled by Copernicus data in very specific O&G upstream activities.	1
Pillar III: Increase awareness	**#OG-5 – Increase awareness within the industrial sector** The largest share of benefits in the O&G upstream value chain is expected to come from end users and not from intermediate users. In this context, more awareness should be raised directly in the industry through presentations in O&G industrial conferences and the provision of tutorials and video capsules on specific O&G interfaces to stimulate awareness about the potential benefits of Copernicus data & products.	1

Renewable energies

Key domain characteristics and specificities

- **This chapter focuses on solar, wind, hydro and biomass renewable energy sources (RES) as they represent about 98% of the estimated renewable energy electricity production and at least 70% of the renewable energy consumption.**
- **The global renewable energy market is growing, global renewable power capacity doubled between 2004 and 2013.**
- **The European renewable energy industry is reported to have generated some EUR 130 billion turnover in the EU in 2012 and employ 8.1 million people.**
- **EO products are mainly used for biomass and solar renewable sources of energy**
- **The market for commercial applications of EO downstream services in the renewable energy sector is rather new, and its size was estimated to be approximately EUR 22.73 million in 2015.**
- **A minimal estimation of the revenues enabled by Copernicus on the European EO market for renewable energies is of EUR 1.8 million in 2015.**

Scope/boundary

As defined by the Renewable energy EU directive, "energy from renewable sources means energy from renewable non-fossil sources, namely wind, solar, aerothermal, geothermal, hydrothermal and ocean energy, hydropower, biomass, landfill gas, sewage treatment plant gas and biogases". This must be understood as energy sources that can be replenished on a short (or human) timescale[301]. **In this chapter, we will focus on solar, wind, hydro and biomass renewable energy sources (RES) as they represent about 98% of the estimated renewable energy electricity production and at least 70% of the renewable energy consumption** (see Figure 100)[302].

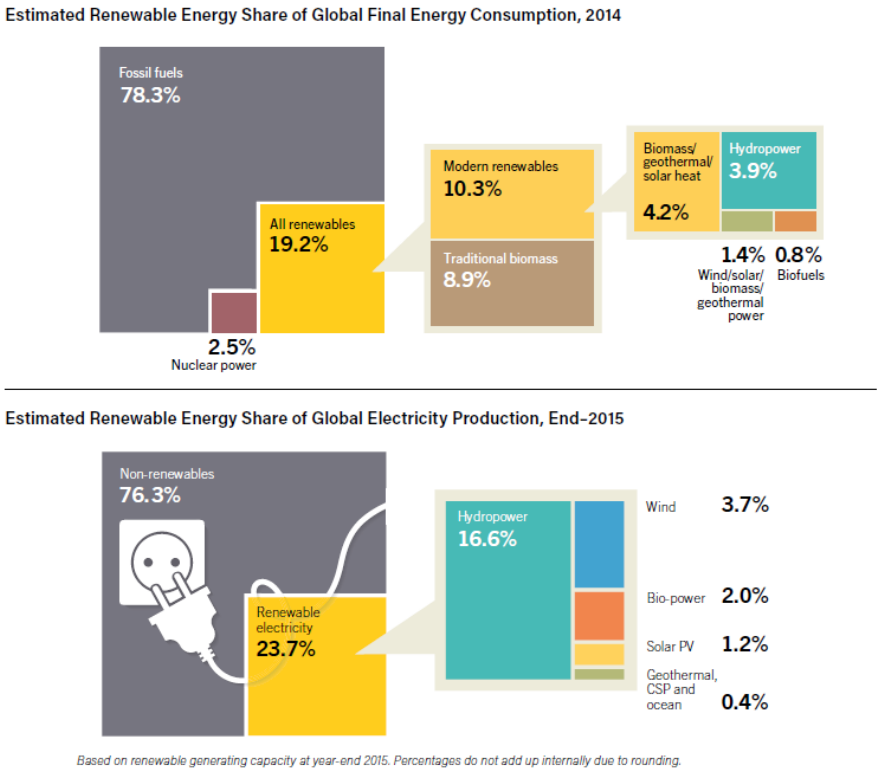


Figure 100 - Estimated RES proportions in the global final energy consumption in 2014 and in the global electricity production in 2015 (Source: REN21)[303]

[301] *EC, 2009. Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC (Text with EEA relevance).*

[302] *REN21, 2016.* Renewable 2016: Global Status Report - Key Findings.

[303] *REN21, 2016.* Renewable 2016: Global Status Report - Key Findings.

Taxonomy and definitions

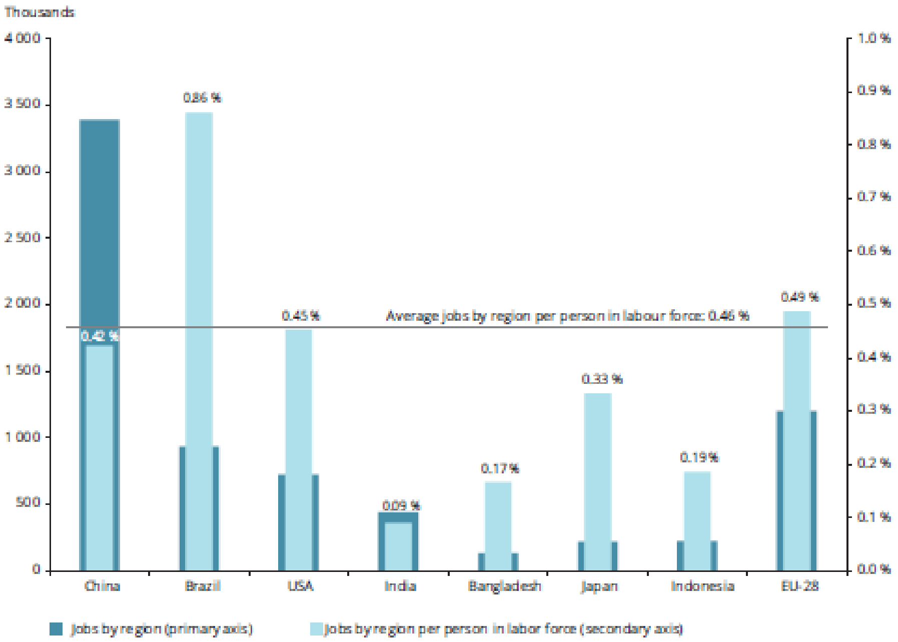
Main definitions related to the renewable energies value chain	
Solar energy	Solar energy is radiant light and heat from the sun that is harnessed using a range of ever-evolving technologies such as solar heating, photovoltaics, solar thermal energy, solar architecture and artificial photosynthesis. Solar energy is mainly produced through solar photovoltaics (PV) or solar thermal energy.
Wind energy	Wind energy (or wind power) describes the process by which wind is used to generate electricity, which can be produced by on-shore or off-shore wind turbines.
Hydroelectric energy	Hydroelectric energy is the term referring to electricity generated by hydropower; the production of electrical power through the use of the gravitational force of falling or flowing water.
Biomass	Biomass is material of biological origin which derives from living or recently living organisms. It is used to produce energy directly by combustion, indirectly through biogas produced by methanisation or through biofuel produced by chemical transformation.

Value chain description

Overview of industry/domain

Renewable energies are a main contributor to the **ecological transition**, which refers to the change from our current mode of production and consumption to a more ecological mode. Compared with fossil fuels, they release less greenhouse gases in the atmosphere and thus reduce the negative impacts on health and environment. Increasing the use of renewables in the coming years is expected to generate new **green jobs** (i.e. "work in agricultural, manufacturing, research and development (R&D), administrative, and service activities that contribute(s) substantially to preserving or restoring environmental quality"[304])[305].

Today, renewable energies globally employ 8.1 million of people[306]. Strong differences in the development of this sector have to be noted at this stage between the different countries, for example in Europe, the countries with most employees in this field are Germany, France and Italy followed by Spain, Denmark, the UK, Sweden, Belgium and Austria. China is the world leader in terms of employment in the renewable energy sector as we can see on Figure 101.



Note: The primary y-axis displays absolute numbers (thousands of jobs) in 2014. The secondary y-axis relates the absolute number of jobs to the total labour force of each region, thus displaying jobs per person of labour force. The jobs displayed include both direct and indirect jobs along the value chain. The data on labour force used to calculate jobs per person in labour force was for 2013, as no data had been found for 2014 at the time of writing this report.

[304] *United Nations Environment Program*

[305] *EEA, 2016. Renewable energy in Europe 2016: recent growth and knock-on effects. EEA Report, No 4/2016.*

[306] *REN21, 2016.* Renewable 2016: Global Status Report - Key Findings.

Figure 101 - Direct and indirect jobs related to renewable energy in 2014 split by region – absolute and per person in labour force (Source: IRENA)[307]

The European renewable energy industry is reported to have generated some EUR 130 billion turnover in the EU in 2012[308]. In 2013, the European solid biomass and biogas sectors on its own generated a turnover of close to EUR 42 billion[309].

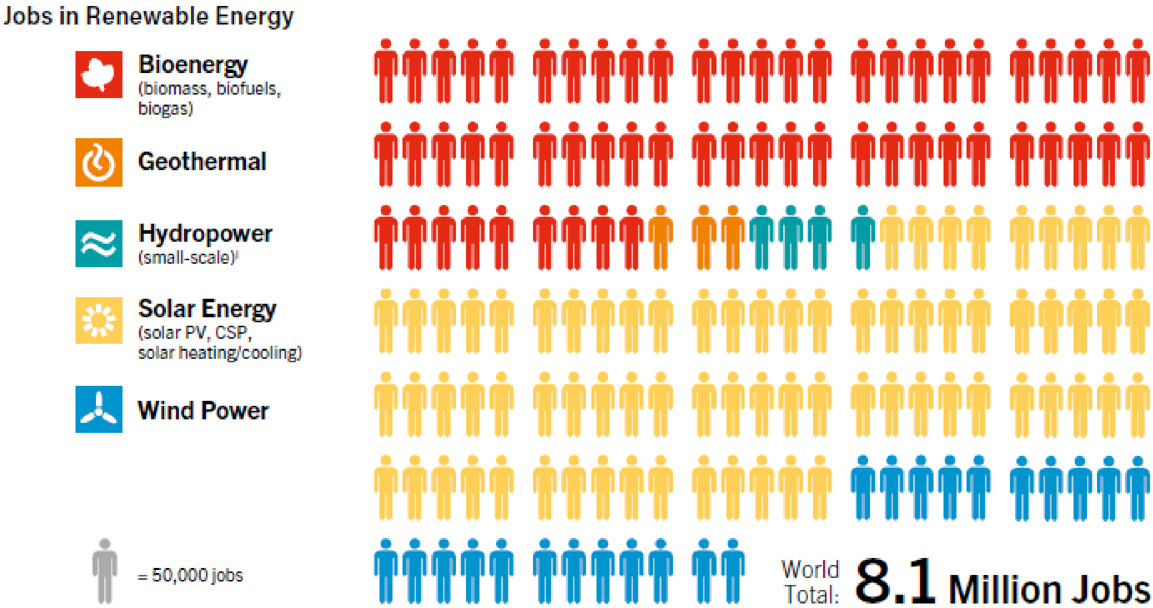


Figure 102 - Jobs in renewable energies (2014-2015) (Source: REN21) [310]

The global demand for renewable energies is increasing and between 2004 and 2014, the total supply has increased by 30%; in 2014[311], the renewable energies supplied approximately 19% of the world's final energy consumption[312]. Solar and wind power are the RES growing faster as we can see on Figure 103.

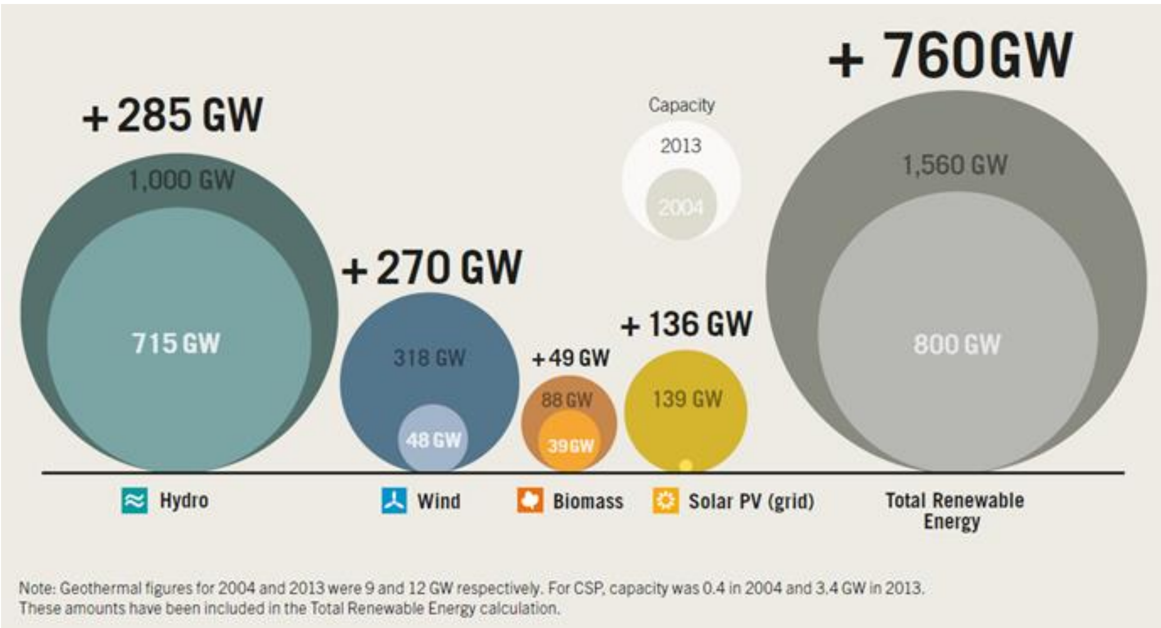


Figure 103 - New renewable power capacity additions by technology, 2004-2013 (source: REN21) [313]

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[307] *IRENA, 2015. Renewable energy and jobs. Annual review 2015*

[308] *European Renewable Energies Federation, 2014. Overview concerning the contribution of renewable energies towards employment and growth within the EU.*

[309] *European Parliament, 2015. Biomass for electricity and heating-Opportunities and challenges.Briefing.*

[310] *REN21, 2016.* Renewable 2016: Global Status Report - Key Findings *.*

[311] *REN21, 2014. 10 Years of Renewable energy progress.*

[312] *REN21, 2016.* Renewable 2016: Global Status Report - Key Findings *.*

As of end of 2015, the vast majority of countries worldwide have **renewable energies policies** and most of the countries have set emission-curbing targets. These policies received a particular attention in 2015 due to the global effort to mitigate climate change in the framework of COP21, the 2015 United Nations Conference on Climate Change which gathered 195 countries[314]. For example, the use of renewable energies is an important priority of EU policies which state that **by 2020, 20% of EU energy should come from renewables** as stated in the Renewable Energy Directive of 2009.

The supply chain of the renewable energies sector breakdowns as presented in the following figure. The first step consists in selecting a potential site, and proceed to feasibility studies to assess whether the solar farm, wind farm or hydropower dam for example should be constructed on this site or not. If it turns out that the site is optimal, it is then necessary to engage procedures to obtain a construction permit. After relevant calculations and modelling by design and engineering teams, facilities are constructed, operated, monitored and maintained all along their lifetime. Once being non-operational anymore, or at the end of the permit duration, facilities are decommissioned.

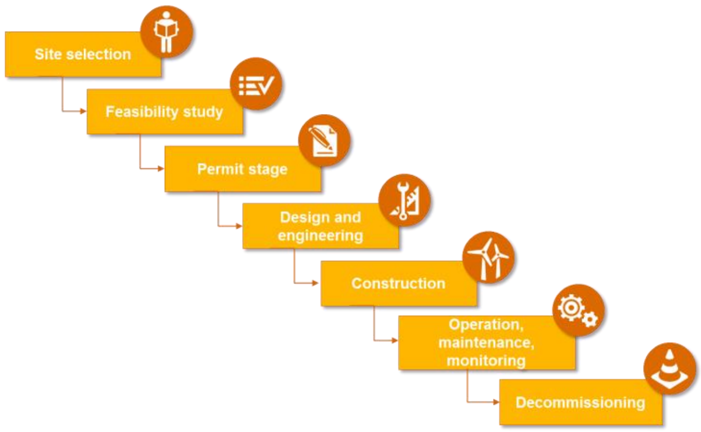

Figure 104 - Renewable energies production generic supply chain (Source: PwC-Strategy& analysis)

However, using renewable energies presents specific challenges all along the supply chain related to their environmental and social impact as well as their intermittent character due to their varying availability depending on climate parameters. That is why, for example, the location and operation of the plants needs to be carefully scrutinized before undertaking any (long-term) investment. We will see in the rest of this analysis how EO provides the right tools to face these challenges.

Other challenges relate to the regulatory aspect. Indeed, in order to mitigate what is often perceived as a "market failure", some governments have tended to promote public policy tools to develop the renewable energy sector, be they price-oriented (feed-in-tariff, net metering), quantity-oriented (quotas, purchase power agreement, central procurement via energy auction) or through other support mechanisms (e.g. via loan guarantees, grants, and tax incentives or assistance in resource mapping)[315].

Value chain characterization from an EO data usage standpoint

Current use of EO data

(M EUROS)	Overall EO downstream market	% of the overall market for renewable energies only	EO downstream revenues for renewable energies
2012	786	2.83%	22.24
2015	911	2.5%	22.73

Table 53 - EO downstream revenues in Europe for the renewable energy industry (Sources: EARSC; PwC-Strategy& analysis)

[313] *REN21, 2014. 10 Years of Renewable energy progress.*
[314] *REN21, 2016.* Renewable 2016: Global Status Report - Key Findings.
[315] *Sanford V. Berg, 2013. Regulatory Functions Affecting Renewable Energy in Developing Countries. The Electricity Journal.*

Our first calculation method is based on EARSC EO Survey tells us that sales of EO downstream services/products to the alternative energy sector (in Europe and Canada) in 2012 were worth EUR 7.80 million[316] and in 2015 EUR 5.50 million[317]. However, EARSC definition of alternative energy corresponds to our definition of renewable energy but excludes hydro and biomass, which account for around 70% of EU renewable energy production[318]. Assuming they account for a similar share of revenues, then scaling EUR 7.80 million and EUR 5.50 million up to include all renewable energies would give a total of **EUR 26 million for 2012, and EUR 18.3 million for 2015.**

Another way to calculate the EO downstream market for renewable energies sector is the following. The European market for commercial applications of EO in the sector of renewable energy sources for electricity is rather new, and its size was estimated to be approximately EUR 10 million in 2011 and EUR 12.10 million in 2015[319]. However, in the EU, in 2013, renewable electricity represented more than 50% of the renewable energy sources consumption in only 5 Member States, so for most of the member states, the other types of final use (e.g. heat) represent more than 50% consumption. If we assume that the EO downstream revenues are dispatched the same way as the consumption by final use and that we decide to keep the ratio of 50% to calculate a minimum estimation of the European market, we obtain a total European EO downstream market for renewable energy of EUR 20 million in 2011 and **EUR 24.20 million in 2015**. If we assume that the growth has been linear between 2011 and 2015, the growth rate is of 4.88% per year and we obtain a total European EO downstream market for renewable energy of **EUR 20.98 million in 2012**.

The market is shrinking with our first calculation method, and growing with the second method. According to our stakeholder consultation, we believe that the most realistic scenario is that the EO downstream market for renewable energy is growing, we will then consider that the second calculation method is more reliable than the first one. Thus, we will calculate weighted averages between our two results for the years 2012 and 2015, giving a weight of 1 to the first calculation method and of 3 to the second calculation method (as it is the most realistic according to our analysis). We obtain EO downstream revenues in Europe for the renewable energy industry of EUR 22.24 million in 2012 and of EUR 22.73 million for 2015, i.e. a growth of 2.2%.

Figure 105 below gives an overview of the EO data used for the different applications by type of RES.

[316] EARSC, 2013. Comprehensive Industry Survey. A Study into the state and health of the European EO Services Industry. 2012 industrial Survey. Under an assignment of the European Space Agency.
[317] EARSC, 2015. A survey into the State AND Health of the European EO Services Industry. Prepared by EARSC under assignment from ESA, September 2015.
[318] EEA, 2016. Renewable energy in Europe 2016: recent growth and knock-on effects. EEA Report, No 4/2016.
[319] Space Tec Partners, 2012. Assessing the Economic Value of Copernicus: The potential of Earth Observation and Copernicus Downstream Services for the Renewable Energy Sources Electricity Sector. Prepared by Space Tec Partners under assignment from the European Commission

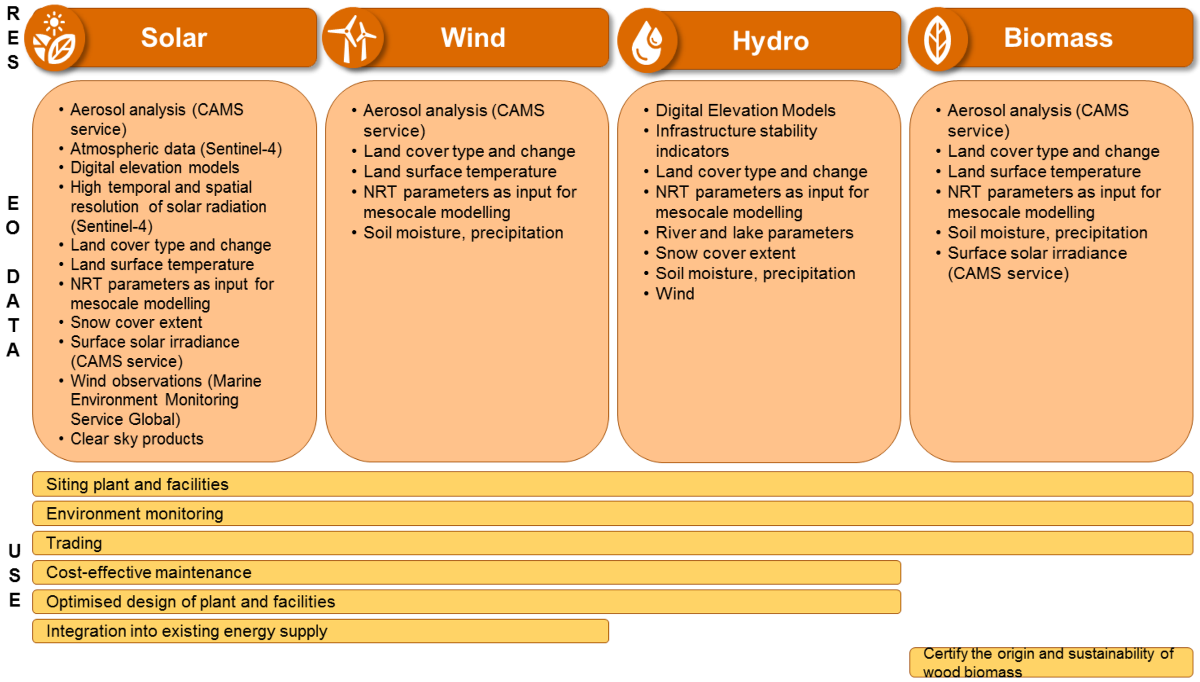

Figure 105 - EO data downstream value chain - Detail per RES (Source: PwC-Strategy& analysis)

EO-based data forecasting and nowcasting of the production of electricity or of fuel is used for PV, windfarms, hydrologic electricity production and biomass for many purposes as detailed below.

Other applications focus on an **optimised on-going and on-demand maintenance** of the sites, often through an early detection of faults. The avoidance of silent failures leads to cost reductions, in particular because traditional maintenance also often requires expensive software and preventive maintenance which are not required with EO-based maintenance. For example, performance monitoring is particularly important for solar plants as the majority of PV plants are remote and unsupervised, panels are subject to failure and output can be affected by dirt, shading or other external damage e.g. vandalism, **the vast majority—in some cases up to 90%—of budgeted operations and maintenance (O&M) expense is preventative maintenance, while a small fraction (roughly 10%) tends to be reactive** and **monitoring equipment represents 1-2% of overall plant installation costs**[320]. For dams too, EO radar data enables an on-going remote maintenance by detecting micro failures in the dams or small landslides in the surroundings.

Forecasting the potential energy production and the analysis of potential sites with EO-based products provide useful information to **site plants, dams and biomass reservoirs, finding the most-productive locations and estimate the environmental and social impact.** Indeed, it allows better cost assessment, estimation of a plant outputs and income predictions, resulting in better investment decisions. For example, the decision-making criteria for siting a wind farm are the amount of wind and the environmental and socio-economic impact.

Forecasting the energy production can also be useful for energy producers to **trade fuel and electricity**, allowing them to anticipate the amount of energy that they could sell.

Regarding the RES in the electricity sector, EO data can contribute to the provision of information for **optimal integration of traditional and renewable energy supply systems into electric power grids**. EO downstream services can bring value at several stages, for example:

- Provision of meteorological and atmospheric data
- Setting up of model irradiance and forecast maps, e.g. ground-based irradiance to measure the amount of ground level solar radiation available on a given site where ground based irradiance sensors could turn inefficient due to dirt, irregularities or the size of the site to be monitored. **Irradiance satellite**

[320] *Space Tec Partners, 2012. Assessing the Economic Value of Copernicus: The potential of Earth Observation and Copernicus Downstream Services for the Renewable Energy Sources Electricity Sector. Prepared by Space Tec Partners under assignment from the European Commission*

values could be less accurate than those coming from ground measurements, but they offer a wide data coverage at high temporal resolution. [321]

- **Forecasting the production of electricity is particularly important in independent areas such as islands, deserts or some rural areas, where it is harder to balance the intermittent output renewables**, in particular when the share of renewables is relatively high. Indeed, on larger grid networks, the intermittent output of solar and wind can be balanced by reliance on other generation and energy storage systems. Forecasting with accuracy the electricity production allows then to avoid electricity shortages and by taking the right decisions at the right time. **In case of failure to supply the demand, the electricity providers may have to pay penalties to the grid managers and the grid managers may have to pay its customers to reduce demand, procure additional expensive supply or pay hefty imbalance penalties**.[322]

Bioenergy is often described as carbon-neutral but **a main issue affecting biomass and biofuels is the optimisation of the production on a sustainable basis.** Participating in carbon sequestration rather than carbon emission can be done for example by harvesting at the right time the right species but it is more challenging when it comes to large scales. Another issue for biomass producers is to be able to **report to governments, NGOs**, etc. and to maintain a stakeholders' engagement. **EO data can both help to monitor biomass and to ensure a homogeneous and accurate reporting to the public institutions.**

European and national institutions seem to be aware of the importance of this segment, since they have launched initiatives in this field. For example, ESA had launched the project ENVISOLAR ("Environmental Information Services for Solar Energy Industries") which aims at producing near-real-time data and solar resource forecasts. Another example is the EC-funded project MESoR on the management and exploitation of solar resource knowledge or the FP-7 project ENDORSE, that aimed at developing a portfolio of pre-market downstream energy services. The DLR also set up SOLEMI ("Solar Energy Mining") a solar resource assessment service to provide Europe, Africa and Asia data on a long-term period regarding solar potential.[323]

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[321] *EARSC portal. Link : he values could be less accurate than those coming from ground measurements, but they offer a wide data coverage at high temporal resolution.*

[322] *Bloomberg New Energy Finance, 2016. Supply-demand balancing system for electricity retailers. Case study.*

[323] *Space Tec Partners, 2012. Assessing the Economic Value of Copernicus: The potential of Earth Observation and Copernicus Downstream Services for the Renewable Energy Sources Electricity Sector. Prepared by Space Tec Partners under assignment from the European Commission.*

Type of applications	End users	Benefits
• Site selection and design of plants or facilities	• Energy providers	• Environmental and social impact assessment • Identification of the site with a maximised energy production
• Production efficiency monitoring	• Energy providers	• Early and cost-effective detection of failure
• Energy production forecasting	• Energy providers • Electricity grid managers	• Improved integration of the produced electricity on the grid
• Energy trading	• Energy and carbon traders	• Optimised trading revenues
• Environment monitoring	• Energy providers • Local and national authorities	• Reduced negative impact of a plant or infrastructure on the encvionmeent, and health,
• Tracing biomass and monitoring the production	• Biomass producers • Local and national authorities	• Compliance with the regulations

Figure 106 - Synthesis of EO applications related to the Renewable energies sector (Source: PwC-Strategy& analysis)

Market structure and trends

The **biggest potential market in terms of revenues is trading**, today, the trading companies are almost exclusively using weather forecasts data, but some VAS companies are considering entering the market with their EO-based products.

Today EO data for **forecasting electricity production of wind turbines is mostly used for research and wind farms are mostly using ground measurements and modelling**. However, the currently used models have limited characteristics in comparison with EO-based products. For example, today the same models are used when the wind farm is close to or far from the coast, without taking into account the fact that the wind climates are different in the two cases. **Introducing EO data in such forecasting models could improve the results** according to the stakeholders of the world of research we consulted, even if the real impact of EO data in these models is difficult to assess as to control their quality, very expensive ground-based sensors are required. **Offshore wind energy is a mature source of energy, especially in northern Europe, Korea, Japan, China and the US, so in order to grow, the wind farm electricity producers will require more accurate information on their production and try to reduce their costs by optimising their production.** Thus, the use of EO data should grow, and the cultural barrier to use EO VAS that exists today should be overpassed. Northern Europe and China are the two geographical areas with the highest growth rate of the offshore wind farm market.

Also **on the PV production market there is this search for cost optimisation, so the energy providers are looking for accurate and fast new products to monitor their solar panels**, EO-based VAS can thus bring them the solution. The EO applications market is more mature for PV solar farms than for siting wind farms. Indeed, **PV energy producers are very receptive to EO-based maintenance of their site**.

Furthermore, **Biomass and bioenergy firms are increasingly required to certify the origin and sustainability of their wood biomass** in order to qualify for subsidies. This trend should lead to an increase of the EO based products users in the field of biomass.

In terms of market structure, historically, when renewable energy markets were not yet structured or regulated by national or European authorities (e.g. windfarm electricity area in France until early 2000's), a myriad of small companies set-up and positioned themselves on what was perceived at the time as a new "Eldorado". Nevertheless, **already existing energy companies (either private or semi-public) having a critical mass, have tended to absorb smaller actors**. The pre-eminence of **EDF in the windfarm sector** in France since the mid-

2000s is quite illustrative from this point of view[324]. As most of the industrial sectors, the renewable energy industry has also gathered into trade associations, notably at European level, to carry the consensual voice of their sector to EU before EU stakeholders, e.g. the European Solar Thermal Industry Federation[325], the European Photovoltaic Industry Association[326], or the European Wind Energy Association[327]. Following the same scheme, the main producers of bioethanol are the **historical Oil & Gas companies such as Shell.** Today, the investment to enter the market is so high that it is almost impossible for an SME to do so.

On a more prospective view, with the increasing world population, the **demand in energies in general is expected to rise, coupled with a rapid growth of the demand in RES**. In particular, demand per capita for electricity should increase despite the expected improvement of energy efficiency. In addition to sustained investments in renewable technologies which are smoothing output variability and driving down the infrastructure costs, regulatory drivers (EU2020) and technological development will make the RES energy sector a key market opportunity[328].

Key Drivers	Key Obstacles
There is an **increasing demand of energy** over the globe	Some energy providers have some **cultural barriers in using EO-based products**
Increased competition on the renewable energies market, which drives the end users to find solutions to cut costs and optimise production	
Some VAS companies start to prepare the entry on the energy trading market	
Biomass energy producers are increasingly required to report on the way they manage their forest of biomass and have to trace their biomass.	

Table 54 - Key drivers and obstacles in the Renewable energies EO market (Source: PwC-Strategy& analysis)

Main players (examples) globally and in Europe

The main intermediate users in Europe in the field of renewable energy are VAS companies or research centres. The VAS companies are SME that are either specialised in a type of EO product, this is the case of **Rezatec** operating in land-based asset management through EO, or **TRE**, specialised in deformation detection, or companies that were specialised on a market and improved their existing products or created new products such as **Reuniwatt**, expert of PV energy production.

Regarding solar energy, most of the intermediate users are SMEs, experts of the sector, which used to provide services to solar power generators and started to use EO data to improve their products. In Europe, main VAS companies producing PV energy forecasts are the SMEs **Reuniwatt** and **SteadySun**.

The **market of wind energy is not yet mature** and consulted stakeholders reported that for them there was not yet a commercial market in this field, the intermediate actors are then **mainly research and development units of big VAS companies** developing new products for entering the market. In Europe, one of the main VAS companies trying to enter the EO market of wind farm electricity production forecasting is **CLS**, which has a good

[324] *Garric, A. L'éolien francais profite aux grands groupes du nucléaire et aux fabricants étrangers (in French). Blog, Le Monde. July, 12 2011.*
Link: http://ecologie.blog.lemonde.fr/2011/07/12/l%E2%80%99eolien-francais-profite-aux-grands-groupes-du-nucleaire-et-aux-fabricants-etrangers/
[325] *European Solar Thermal Industry Federation (ESTIF) website. Consulted December, 7 2015.*
Link: http://www.estif.org/
[326] *Solar Power Europe website. Consulted December, 7 2015*
Link: http://www.solarpowereurope.org/home/
[327] *European Wind Energy Association website. Consulted December, 7 2015.*
Link: http://www.ewea.org/
[328] *Space Tec Partners, 2012. Assessing the Economic Value of Copernicus: The potential of Earth Observation and Copernicus Downstream Services for the Renewable Energy Sources Electricity Sector. Prepared by Space Tec Partners under assignment from the European Commission.*

expertise in producing wind maps from SAR. **Research agencies** should not be forgotten, considering that renewable energies development has been relying on R&D progress to decrease their cost price and the efficiency of the energy. As an example, the improvement of wind turbines' blades is considered to have been a factor enhancing electricity production. Similarly, the power of terrestrial wind turbines is estimated to have been multiplied by 10 between 1997 and 2007, showing the importance of innovation in this sector[329]. Today, **DTU,** who works closely with wind power producers for its research, and **DLR** are doing research on EO applications in the field of wind farms, looking for commercial markets for their applications.

Data flow along the value chain

Data collection and processing platforms

The intermediate users procure a wide range of different EO data.

For **dam maintenance**, **LIDAR and Sentinel-1** are used and **Envisat**, Sentinel-1's predecessor, is used as historical radar data (2002-2012). Sentinel-1 has a real competitive advantage for surface detection, also on other free radar data (e.g. UNAVCO), as it allows to detect moves down to one millimetre.

For **siting renewable energy sources** such as dams, biomass production, windfarms or solar farms, **Copernicus land use and land cover data** are used and downloaded through the **CLMS**, this kind of data is useful. Digital elevation models and land cover for example can be used to analyse an area and select a site for dams or wind turbines (as the quantity and strength of the wind depends on the position of the turbine).

For **power production forecasting**, the most used data is **American weather forecasting** mainly because it is free. **Meteosat** can also used for specific data such as images every 30 minutes which help to track cloud and forecast solar power production.

The analysis of the composition of the atmosphere is particularly important for **forecasting solar power production**. Data such as **clear sky models** (which estimates irradiation under clear-sky)) and **aerosols** analysis are necessary and in this field **CAMS** provides free and easy-to use products.

For forecasting **wind farms power production**, the winds characteristics can be analysed based on wind observations available on the global Copernicus Marine Environment Monitoring Service for offshore farms and on the Copernicus Land Monitoring Service for onshore farms.

Land surface temperature, snow cover analysis and surface solar irradiance can be used for forecasting the **level of water in dams**.

Outsourced and in-house capabilities

Only the large energy producers have created products based on EO data, this is for example the case of EDF with its EDF Store and Forecast, created in 2014, which sells PV production forecasting products using satellite data or which are used for their own electricity production but they are also service providers.

Less integrated historical energy companies buy EO based services from VAS companies such as Reuniwatt or Steadysun.

Development of value-added software, products and applications

For **wind turbines**, it is important to have a large quantity of data because winds are changing fast and are hard to forecast. Ground-based data is first used to validate the satellite data and the satellite data is then used to extrapolate the ground-based data to different heights (as ground data has a limited height). For estimating the production of off shore wind farms, different sources of satellite data can be used together, such as Envisat (historical data) and Sentinel-1 (historical and real time data). To produce windfarm electricity production forecasts, a deep expertise both in SAR and in wind energy is required. For siting on shore wind farms, land use is used to model the studied field, the trees and to define and map the level of roughness of the surface for the wind turbine implantation.

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[329] *Connaissances des Énergies" website. Consulted December, 7 2015.*
Link: http://www.connaissancedesenergies.org/fiche-pedagogique/eoliennes-terrestres

In order to make a **performance diagnosis of a solar farm**, one of the VAS providers consulted for this study was using **50% of EO data and 50% of ground-based measurements**, the EO data being used to calibrate the interpretation of the measurements.

For PV production forecasting, 100% of the data used is from EO, it includes historical data, near-real time data, meteorological and atmospheric data (cloud, water vapour, aerosols, dust) in particular clear sky models. Clear sky models allow to calculate the maximum power production for the next years (the production in ideal cases in which they would be no clouds), then with data such as Meteosat data, the quantity and the quality of the clouds can be forecasted and the production forecast is adjusted accordingly. The most important factor to measure for such forecasts is the amount of ground-level solar radiation available on a specific site. This can also be measured by ground-based sensors, but these are costly, susceptible to failure, dirt and irregularities. Satellite data provides a cost-effective alternative and/or complementary option to ground-based measurements, and in certain cases (such as large, remote and/or unsupervised plants), satellite monitoring is the only option for predicting solar irradiance. For example, for solar plants, the expected output is a function of the efficiency of the panels and their inclination, whether they are static or mobile (tracking the sun), the solar irradiance over the area and the factors which affect it, such as cloud cover. Such forecasts can also be used to select the best site for a power plant.

For EO-based PV plant maintenance, the gap between observed output and the expected output is analysed. Any discrepancy indicates that there is a fault either of the output monitoring sensors (usually due to dirt or damage) or on a panel. In both cases, the maintenance team can target the potential sources of faults, reducing the time before the fault is repaired, and thus, improving the plant productivity.

Land cover type and change as well as information on the snow cover extent (fusion of radar and optical imagery) is useful for **hydropower**, as well as infrastructure stability indicators and rivers and lakes parameters.

Biomass management relies on EO products such as historical and current land cover, the topography, soil types, soil moisture, precipitations, land surface temperature and current land use, which can come either from satellite imagery, low- and high- resolution optical data, RADAR, LiDAR or airborne imagery from planes and UAVs. All this data is combined and sometimes enriched with ground data where available. From this information, VAS companies such as Rezatec manage to produce carbon stocks estimates and accurately identify the carbon impact of producing biomass from forests over extended periods of time.

In general, **EO data enables to extend and harmonise in situ datasets.**

End users

Energy providers are the main end users of EO products related to renewable energies. They are the clients of the VAS companies that produce for them the required analysis, forecasts or system. The use of such products by energy providers impacts positively on the work of the **grid managers**, who are thus indirect end users. **Suppliers to renewable energies generators** are also end users, they are mainly surveying, environmental and engineering consultants and key actors when siting or designing plants.

On the public side, **State and local decision makers** should receive the site selection analysis for a new energy producing-facility in order to authorise a new site construction. Renewable energy agencies and municipalities are also important end users to be considered, since they have to bear in many countries binding objectives (under potential penalty) with respect to their local "policy mix". In Europe, these cities have also gathered into associations in order to maximize exchanges of good practices and make their voice heard before EU authorities[330].

[330] *See the website of Energy-cities: http://www.energy-cities.eu/spip.php?page=index_en*

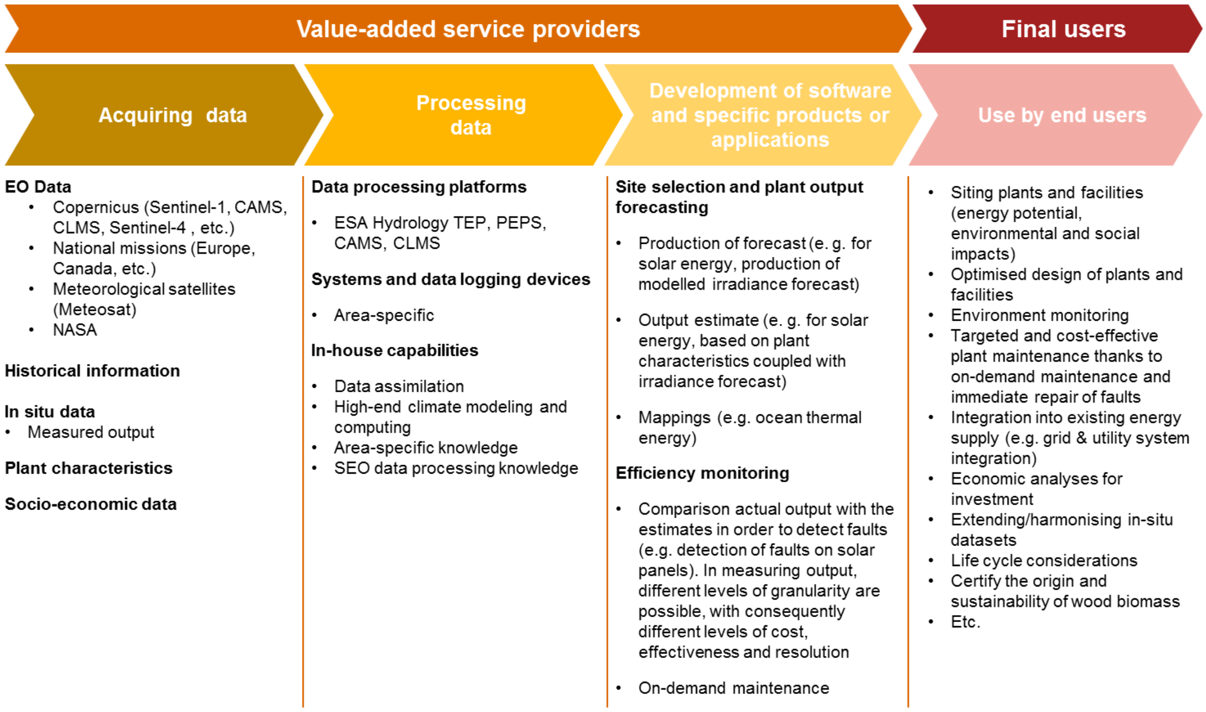

Figure 107 - Data flow along the Renewable energies value chain (source: PwC-STRATEGY& analysis)

Current role of Copernicus

Copernicus data

Sentinel-1A is the first satellite that has been specifically designed to propose radar images that cover large areas and that enable the comparison of different ranges of values taken at different times.

Sentinel-1A allows VAS companies operating in the field of renewable energies to develop **new products** as it provides some data that were not available from any other source. This is the case for example for the detection of landslides, unstable slopes, buttresses and active fault structures in dams supporting embankments as Sentinel-1A data provides the required historical data. It is used to monitor the **stability of dam structures and of the surrounding areas** by detecting the deformations to millimetre accuracy and identifying movements can indicate structural weaknesses. The stability of containing slopes and embankments can also be accurately measured, highlighting weaknesses that could lead to reservoir breaches. Such deformation maps can be used as input to risk models which identify the dangers to downstream areas. By utilizing an extensive archive of radar imagery, historic deformation data can contribute to the identification of stable sites for dam and reservoir development. Given the high density of ground measurement points detected, the reservoir water level can be estimated by monitoring the water / reservoir boundary.

When two or several **wind farms** are close to each other there is loss of wind after it went through a wind farm, **Sentinel-1** can help to **measure this loss and make forecasts**. It can also be used to **observe the ocean surface and thus create a wind map** for forecasting the production of offshore wind turbines. Sentinel-1 also enables the **creation of elevation models**, as it provides a wide coverage and is equipped with C-band Synthetic Aperture Radar Data, for siting on-shore wind farms.

For **biomass** management, Copernicus SAR is used and in some cases, replaced LIDAR. CLMS can also be used to monitor the biomass stocks.

Copernicus Core Services

A few of the Copernicus core services are used to deal with renewable energies:

- **Copernicus Land Monitoring Service (CLMS)** provides global observation on **wind characteristics**, such as speed, field or stress. **Corine Land cover** is used for positioning wind turbines, on a site where the energy production is maximised, that is far enough from housing but close enough to the grid in order to minimise the loss of energy in transportation. **Copernicus Digital Elevation Model** is also used to study the relief and so the areas where there is wind. This can therefore be of interest when undertaking Energy resource assessment for selecting off-shore wind farm sites, coupled with the global wind observations provided by the Copernicus Marine Environment Monitoring Service.
- Copernicus Marine Environment Monitoring Service (CMEMS) provides information on sea surface winds.

- **Copernicus Atmosphere Monitoring Service (CAMS)** has enabled so far the development of products encompassing time-series of **solar radiation** reaching Earth's surface in periods of good (bright) weather, the calculation of surface solar irradiance and the monitoring of weather uncertainties affecting solar radiation conditions (e.g. clouds, aerosols, water vapour and ozone). CAMS provides also **McClear**, a free clear sky model, which is an integrated model which delivers data without clouds, available with a 24 hour delay. McClear is very useful for solar PV power production forecasts.

Copernicus Core Service	Products	Application
Copernicus Marine Environment Monitoring Service	• Sea-surface winds	• Offshore wind farm production forecasting • Offshore wind farm siting
Copernicus Atmosphere Monitoring Service	• Solar radiation • McClear (clear sky model) • Aerosols	• Solar farm production forecasting • Solar farm siting
Copernicus Land Monitoring Service	• Corine Land Cover • Land use • Digital Elevation Model	• Onshore wind farm production forecasting • Onshore wind farm siting • Biomass production monitoring

Table 55 - Main products of the Copernicus Services related to renewable energies (Source: marine.copernicus.eu, atmosphere.copernicus.eu, land.copernicus.eu)

Copernicus socio-economic impact assessment

This impact assessment is based on literature and on the consultation of 12 stakeholders including 7 private actors (6 small and 1 micro companies), 2 public organisations, 2 research centres and 1 association.

Copernicus current enabled revenues

In order to calculate the gross revenues enabled by Copernicus in the field of renewable energies, the various types of benefits are decomposed as illustrated in Figure 108.

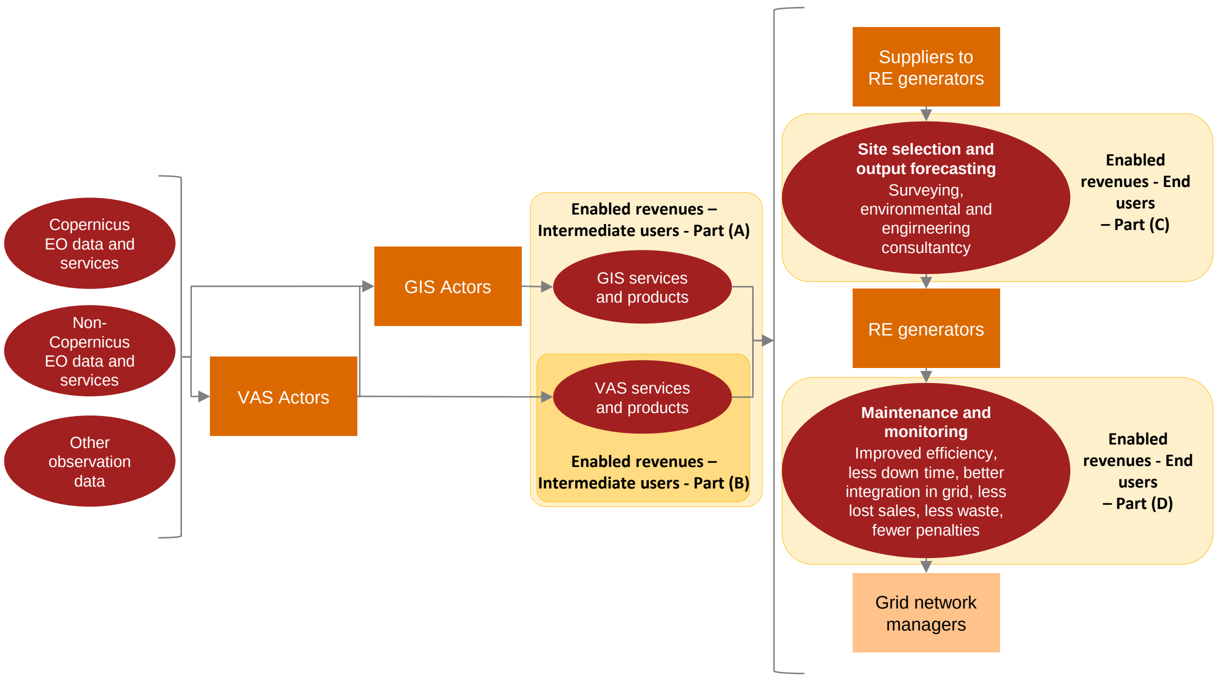

Figure 108 - Decomposition per actors of the gross revenues enabled by Copernicus (Source: PwC-Strategy& analysis)

Revenues enabled by Copernicus can thus be decomposed into four parts:

- **Part (A):** the sales of GIS services/products to renewable energy supply chain;
- **Part (B):** the sales of EO VA services/products to renewable energy supply chain;
- **Part (C):** the sales of products/services from suppliers to renewable energy generators that are enabled by services/products based on EO;

- **Part (D):** the increase in revenues for the renewable energy generators enabled by EO-related products/services because it leads improved production efficiency. This increase of revenues is due to more accurate and timelier maintenance which results in less down time overall and less down time peak production periods. These results in an overall increase in the amount of energy generated. Combined with better integration with the grid, less energy is lost/wasted and fewer penalties are paid, leading to an increase in the amount of energy sold to suppliers/customers, hence an increase in revenues (assuming any impact on price is small or negligible).

For calculating the **part (B)**, being the sales of VA services/products to renewable energy supply chain, according to the stakeholder consultation **for most VAS companies operating in the field of renewable energies, and except for Sentinel-1, Copernicus data represents a minor part of the used data source and it could be replaced**. The sales of EO downstream services/products to renewable energies is estimated to be of EUR 22.73 million, and considering the 8% of VAS companies' revenues enabled by Copernicus in the Oil & Gas (which is an already mature EO market) analysis of this report as an upper threshold, it represents **EUR 1.82 million in 2015 of revenues for intermediate users related to renewable energies directly attributable to Copernicus, GIS companies excluded.**

For calculating the **part (A)**, it is assumed that the share of renewable energy in the revenues generated by GIS data and services is the same as the share of renewable energies in the revenues generated by the EO, i.e. 2.5% in 2015 (cf. supra 'Market structure and trends'). The European market of GIS for data and services being estimated at EUR 1.337 billion for 2015[331], the European market of GIS data and services for renewable energies is of EUR 33.43 million. The share of Copernicus data and services in the input data used by GIS actors is assumed to be the same as the share of Copernicus data and services in the EO data used by VAS actors. Considering that the revenues generated by Copernicus data among the data used by VAS actors is estimated to be part (B), i.e. EUR 1.82 million, and that the overall revenues generated by VAS actors in the field of renewable energies is of EUR 22.73 million, the share of Copernicus is of 8.01%, representing a total of **EUR 2.68 million.**

The end-users' benefits could not be quantified at this stage as there remains too much uncertainty on the actual share of their revenues that can be attributed to Copernicus itself. Considering the amounts involved, a lack of precision on this estimate could lead to substantial gaps with the actual Copernicus-enabled revenues.
Part (C) is the sales of products/services from suppliers to renewable energy generators that are enabled by services/products based on EO. It can be considered that activities related to site selection, plant design, output forecasting are outsourced/carried out by external stakeholders such as consultants and that these sectors sell the products/services to renewable energy generators. To give orders of magnitude, assuming that the revenues grew at the same pace as the consumption of renewable energies, and considering a figure of the European Renewable Energies Federation who estimates that the European renewable energy industry generated EUR 130 billion in revenues in 2012[332], the European renewable energy industry should have generated about EUR 147 billion in 2015. From an analysis of EU28 Input-Output tables[333], it can be estimated that this requires purchases from suppliers of site selection, plant design and output forecasting services of around EUR 1.40 billion. It seems reasonable to assume that the proportion of these revenues attributable to Copernicus is greater than 0% but remains small given the immaturity of the market. As an illustration, an assumption that just 0.1% of the revenues are enabled by Copernicus would lead to EUR 1.40 million enabled revenues.

Part (D) is the increase in revenues for the renewable energy generators enabled by EO-related products/services as it leads to improved production efficiency. The renewable energy revenues are estimated to be in the order of EUR 147 billion in 2015. If 1% of the revenues were directly attributable to Copernicus, this would equate to something in the region of EUR 1.47 billion in 2015, which is a substantial amount.
The literature research and the stakeholder consultation results suggest that the commercial market of EO based applications for wind power is not existing yet (but research show that the results are good and stakeholders are communicating about it) and the EO based applications for hydraulic power are not directed at increasing revenues (and more at managing the risks). Given the dominance of these two renewable energy sources, and the fact that most of the products based on Copernicus data and services are quite recent and the investments made by the renewable energies generators may not have paid off yet as much as they will in the coming years, it can be assumed that **for a conservative scenario any increase in revenues enabled by Copernicus is zero**. Similar to part C, as an illustration, even assuming a very low penetration of Copernicus data (for instance 0.001%), the resulting enabled revenues would be substantial, reaching EUR 1.47 million in this example.

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[331] *Technavio, 2015. Global GIS market 2016-2020.*
[332] *EEA, 2016. Renewable energy in Europe 2016: recent growth and knock-on effects. EEA Report, No 4/2016*
[333] *EEA, 2016. Renewable energy in Europe 2016: recent growth and knock-on effects. EEA Report, No 4/2016*

This end-users analysis needs to be treated with caution as it is based on **purely illustrative assumptions** on the share of suppliers' revenues generated by Copernicus (0.1% and 0.001%) and is not meant to provide an actual quantification of Copernicus economic benefits for the end users.

Extrapolation of the results until 2020

For calculating forecasts for **Part (B)**, it is assumed that the European **VAS actors** market for renewable energies will grow at the same rate as the growth of the production of energy coming from renewable sources in the European Union, and that the share of Copernicus data and services remains constant, at its current rate of 8.01%. The results for this **conservative scenario** are based on European Environment Agency's figures[334]:

(M EUROS)	EO downstream market for renewable energies	% of Copernicus enabled revenues	Copernicus benefits for intermediate users (conservative approach)
2015	22.73	8.01%	1.82
2020	44.88	8.01%	2.44

Table 56 - Copernicus current and forecast enabled revenues for renewable energies generated by EO downstream actors (source: PwC-Strategy& analysis)

However, the stakeholder consultation leads to believe that the use of EO data and product in the field of renewable energies should increase and Copernicus should be increasingly used within the VAS companies. For an optimistic scenario, the intermediate users' basis is expanded to the wider GIS market, restricted to data and services sales (represented by **part (A)**). It is assumed that the share of the renewable energies in the GIS data and services market remains constant and that the share of Copernicus data and services also remains constant, at the current rate of 8.01%.

(M EUROS)	GIS data and services market for renewable energies	% of Copernicus enabled revenues	Copernicus benefits for intermediate users (optimistic approach)
2015	33.43	8.01%	2.68
2020	52.20	8.01%	4.18

Table 57: Copernicus current and forecast enabled revenues for renewable energies generated by GIS data and services companies (source: PwC-Strategy& analysis)

The Figure 109 sums up the different estimates made on conservative and optimistic assumptions.

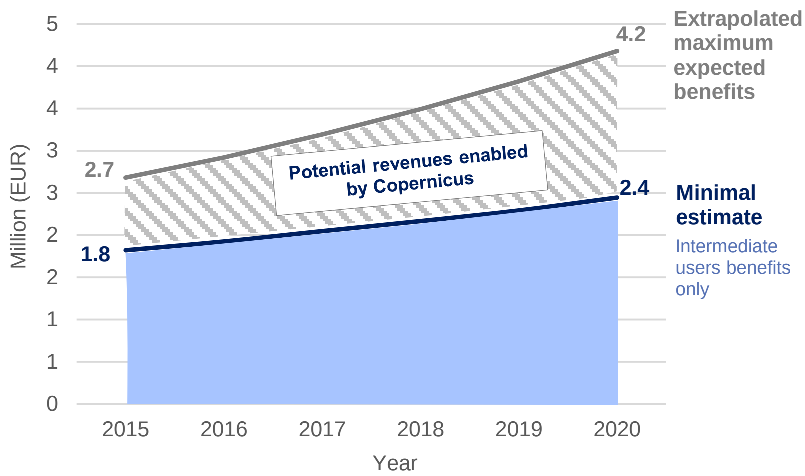


Figure 109: Current and prospective enabled revenues by the availability of Copernicus data in Europe for Renewable Energies (source: PwC-Strategy& analysis)

[334] *EEA, 2016. Renewable energy in Europe 2016: recent growth and knock-on effects. EEA Report, No 4/2016*

Over the period 2015 – 2020, Copernicus-enabled revenues in the renewable energies value chain are forecasted to support a total estimated **between 100 and 150 person years** within the EO and GIS downstream markets across Europe.

It is assumed that productivity among the end users in the renewable sector was the same as for the industries NACE 35.11 and NACE 35.3 and that productivity among the intermediate users was the same as for the industries NACE 62.01 and 62.02. The enabled employment estimation method used employment, turnover and GVA data from the Eurostat Structural business statistics. The 2020 estimates were based on E3ME growth projections for these variables.

Impact of Copernicus in terms of market effect

For most VAS companies operating in the field of renewable energies, and except for Sentinel-1, Copernicus data represents a minor part of the used data source which could be replaced by other EO data. However, is some cases, Copernicus is considered as the best available options.

For solar energy, McClear simple to use and provides the required data, already computed and corrected for aerosol data and for free (which is not the case of MERA, MeteoFrance or ECMWF data) with the right revisit frequency (which is not the case of MODIS). In particular, McClear does not require a long training in comparison with some other clear sky models so it reaches a larger public. For Reuniwatt (see the case study below), Copernicus McClear and raw data on dust, water vapour and ozone increased the accuracy of their solar power production forecast by up to 28% when compared to satellite based forecasting which do not use Copernicus. McClear accelerated their R&D as they did not have to create a clear sky model from scratch (estimated work: 1.5 year for 13 FTEs). CAMS also enabled them to create new products as they can sell processed raw data and be competitive on this market.

For windfarm electricity production forecasting, Sentinel-1 provides a very good quality data (slightly better than Envisat's data) that can be integrated into models. However, it is really hard to assess the real impact of EO and so of Copernicus in these models as for doing so, very expensive sensors are required and the information on the production is kept confidential by the wind farm managers. The biggest value of EO and in particular of Copernicus stands in the very early stages for siting a farm but there is not yet a commercial market on this activity.

For **biomass management**, Copernicus frequency is much higher than other commercial data and it is also cheaper. SAR really adds value where some VAS companies used to pay for LIDAR. Copernicus is not only cheaper but it is efficient in terms of cover and continuity in the long term. A consulted VAS company explained that thanks to Copernicus, their **market increase of about 20% due to the related cost-savings**. **Copernicus also increased the quality of their products by 50%.**

Non-monetary benefits of Copernicus

In terms of social impacts, renewable energy is a sector which creates jobs. For example, in 2013, the European solid biomass and biogas sectors employed 380.200 people, including many in rural areas[335]. Copernicus, by fostering the development of this market, contributes to the associated **job creation**.

As Copernicus helps to monitor biomass, it also helps to **reduce the emissions of greenhouse gases** by triggering the production of biomass. Indeed, the biomass is considered as carbon neutral as when the carbon released when solid biomass is burned will be re-absorbed during the tree growth. However, biomass combustion can have a negative impact on air quality and soil property and thus on human health and on the environment. This is why it is very important that the biomass production and combustion is closely monitored.

Copernicus and in particular the Land service can help monitor land use and **create a balance between agriculture, biomass and solar farms**, which can be in competition for same area.

Strategically speaking, Copernicus contributes to the increase of production of renewable energies by making them more cost-efficient, thus it contributes to **reducing the dependence to fossil fuels.**

[335] *European Parliament, 2015. Biomass for electricity and heating-Opportunities and challenges.Briefing.*

CASE STUDY

How Reuniwatt uses Copernicus to facilitate the penetration of PV energy and increase PV energy producers' remuneration[336]

Presentation of the project

REUNIWATT is a start-up of about 15 people created in 2010 in Reunion island which specialised in renewable energies and in information and communication technologies. Its main product is **Soleka, which forecasts solar power production for electricity grid managers and photovoltaic (PV) electricity producers** in order to ease the introduction of renewable energies in the energy mix.

Soleka can deliver forecasts with three different temporal horizons:

- T+30 min: based on a camera tracking the clouds and on CAMS atmospheric data which provides images without clouds and aggregates data on dust and water vapour.
- H+6 hours: based on satellite images processing. 90% of the data comes from geostationary satellites such as Meteosat which provides images every 15 minutes for tracking clouds, Reuniwatt then extrapolates the data in order to predict the clouds movements and the cloud transmittance (a scientific concept close to opacity) to build a cloud cover map. This result is then combined with a clear sky model using CAMS atmospheric parameters.
- H+24 hours: today based on weather model forecast combined with in situ data and historical data, but soon Reuniwatt will use CAMS data on dust in order to rectify the atmosphere transmittance.

In the three cases, statistical post-processing is used to adjust the other forecasts.

Electricity grid managers must be able to make sure that supply and demand for electricity are equal at any time. However, solar power is an intermittent energy, which makes it highly dependable on the weather. Soleka makes this energy guaranteed and **enables the electricity grid operators to handle the commitments and dispatch generators for securing reserve in real-time**.

Today, the electricity grid manager is not allowed to adjust the forecast they have made the day before but the legislation is changing, giving them more flexibility. Reuniwatt is today bound to providing forecast for the next 24 hours to its clients and cannot adjust it once it is sent. Thus, with the legislation to come, Reuniwatt will be able to inform the operator that an adjustment is required.

PV electricity producers are legally bound to provide the electricity grid manager with forecasts 24 hours ahead of the production and they have to pay penalties or suffer shortfalls if the production differs from the forecast. For example, in the French oversea territories, the French Regulatory Commission of Energy regulates the losses and penalties, allowing a 5% error margin to the PV electricity producers for their forecasts. Soleka forecasts provide crucial information for **minimising surcharges and regulatory penalties for PV electricity providers** which are hold responsible for providing to the electricity grid operator the quantity of electricity they have forecast the day before.

Uncertainties of day-ahead forecast increase with time horizon so intraday forecast updates enable to anticipate adjustment mechanism and reduce the cost of inaccurate forecast. **Satellites, including Copernicus, are**

[336] *Cros, S., Buessler, E., Huet, L., Sébastien, N., Schmutz, N., 2015. The benefits of intraday solar irradiance forecasting to adjust the day-ahead scheduled PV power.*

providing data for the next 6 hours and thus, provide more reliable information than T+24hours meteorological data based forecasts.

Research carried out by Reuniwatt shows that 4 updates per day of the satellite data based forecasts is optimal at a scientific level as more updates only bring negligible improvements, however, it is more realistic to consider that it will be possible for grid managers to make up to 2 updates per day.

Copernicus enabled revenues

Reuniwatt has analysed the results of a fictional PV plant based on the data collected for the day of 8 April 2013 in Carpentras, south of France. It was a day of equinox so generalizable to the rest of the year and during that day, the weather was cloudy in the morning and sunny in the afternoon.

In Figure 110, we observe a significant error of the meteorological model forecast in the morning. This severe overestimation is mitigated thanks to forecast updates based on satellite data. We can see that adding Copernicus in the model does not always provide more accurate forecasts than those based solely on other satellite data, as it is the case between 7:45 and 10:15 in Figure 110. However, Copernicus has **globally improved the accuracy of the forecasts based on other satellite data.**

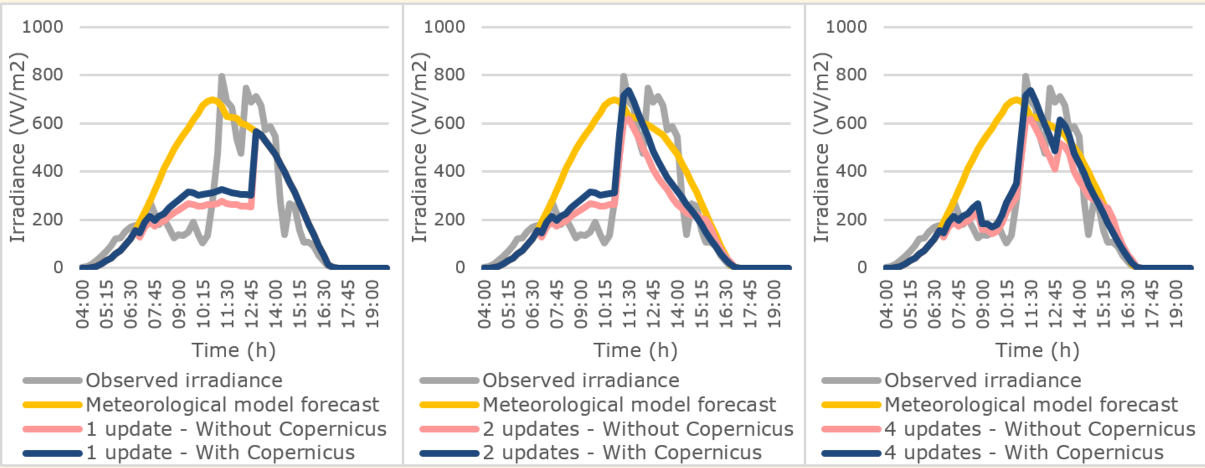


Figure 110: Updating day-ahead forecasts with intraday forecasts based on satellite data with and without Copernicus (source: Cros, S., Buessler, E., Huet, L., Sébastien, N., Schmutz, N. (2015)

The Figure 111 compares the normalised root-mean-square error (RMSE), which is a frequently used measure for the difference between predicted and observed values, of forecasts with and without Copernicus data. After 2 satellite forecast updates, **the addition of Copernicus data makes the error rate fall from 48% to 44% in our case study.** Reuniwatt demonstrates that **adding Copernicus data in the model significantly improves the accuracy of the forecasts based solely on other satellite data.**

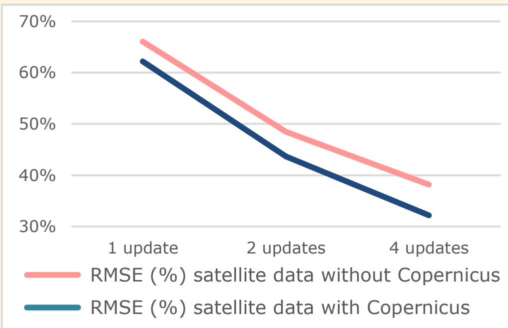


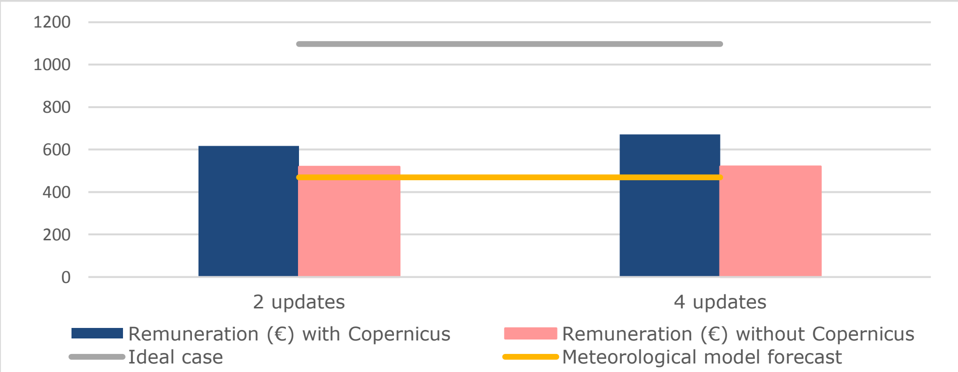
Figure 111: Comparison of the error margin of the satellite based forecasts with and without Copernicus (Source: Cros, S., Buessler, E., Huet, L., Sébastien, N., Schmutz, N. (2015))

More generally, **Reuniwatt research demonstrates that forecasts based on satellite data has a 30% error rate for the next 2 hours, and injecting Copernicus data in the model makes the error rate fall to 25%.**

The level of quality is improved thanks to the information on aerosol, and ozone provided every 3 hours by CAMS. **Indeed, a classic clear sky model, based on climatic means for these variables, has an error rate of 6% whereas a clear sky model using real-time CAMS values has an error rate of 3%**.

The evaluation of this economic value of more accurate forecast for electricity grid managers is highly dependent on several factors such as the size of the network, the capacity of connecting to a foreign grid, the capacity for the grid operator to take production forecasts into account or the climatic conditions. However, for this case study, Reuniwatt managed to estimate the remuneration in function of the number of forecast updates. This remuneration is calculated for forecasts both with and without Copernicus data.

As shown in Figure 112, in the conditions of our case study, Copernicus would have brought a **2% increase of the PV energy producer remuneration**. Reuniwatt demonstrated that the use of Copernicus and satellite based forecasts **supplies a benefit of up to 50% in term of PV production economic value in comparison with the today used T+24h meteorological forecasts**.



Assumptions:

Feed-In Tariff = 100€/MWh

Figure 112: Remuneration depending on the number of forecast updates and the use or not of Copernicus data (Source: Cros, S., Buessler, E., Huet, L., Sébastien, N., Schmutz, N. (2015))

For the T+30 and H+6 products, Reuniwatt estimates the reduction of costs related of 15% as it makes them save time in their data processing. Copernicus has also **accelerated their R&D** as otherwise they would have had to create a whole clear sky model from scratch (about 1.5 years for 13 FTE). **For the H+24, adding Copernicus data improves the quality of the forecasts by 30%.**

Non-monetary benefits of Copernicus

At the level of Reuniwatt, Copernicus has slightly helped them to develop their network through the various events and it has had a strong organisational effect as it resulted in the recruitment of one EO expert.

At much broader level, generally grid managers prefer to secure the electricity supply by limiting the amount of PV energy in their grid, in order to avoid costly adjustments in case of forecasting errors. By improving PV electricity forecasts, **Copernicus contributes to a better penetration of PV energy** in particular in isolated areas such as insular zones or desert, **reducing our dependence of fossil fuels and limiting greenhouse gas emissions**.

Copernicus projected contribution to the global and European socio-economic impacts

On wind energy, data interpretation methods are reported to be still perfectible, while R&D on wind-energy site mapping and monitoring should be continued and existing re-analysis systems be improved.

Climate change will make the electricity production forecasting activities harder as the historical data will lose a part of their value. Near real time data will then be more useful.

With the launch of Sentinel-3**,** the redundancy of the radar data will be higher, which is key for the quality of the deformation analysis. One of the companies we have interviewed, working of the structural stability of dams, declared that they expect at least **20% of their revenues to be based on Copernicus services in 2017 thanks in particular to Sentinel-3.**

Sentinel-4 will provide atmospheric data and high temporal and spatial resolution of solar radiation. In terms of products, CAMS will be then expected to provide global surface solar irradiance monitoring and aerosol analysis and forecasts[337]. It will contribute to Copernicus solar resource monitoring by providing[338]:

- A continuous operational European capacity for atmospheric monitoring
- High temporal and spatial resolution monitoring of solar radiation
- Coherent information on atmospheric variables in support of European policies

Economic	• **For solar energy,** Copernicus McClear helps increase the quality of solar power production forecasts. One company interviewed estimated that by **the quality of these forecasts rose up by 28%, and that McClear accelerated their R&D** (as they did not have to create a clear sky model from scratch). • **For biomass management**, **Copernicus frequency is much higher than other commercial data and also much cheaper**. Copernicus is also efficient in terms of cover and continuity in the long term, thus enabling costs savings (a consulted VAS company estimated their **market increase of about 20% due to the related cost-savings**. Copernicus also **increased the quality of their products by 50%**.) • *With the launch of **Sentinel-3**, the redundancy of the radar data will be higher, which is key for the quality of the deformation analysis. One of the companies interviewed declared that they **expect at least 20% of their revenues to be based on Copernicus services in 2017** thanks in particular to Sentinel-3 (expected)* • ***Sentinel-4** will provide atmospheric data and high temporal and spatial resolution of solar radiation, thus **enabling the creation of new products** (expected)*
Social	• Renewable energies is a sector which **creates jobs** (8.1 million employees globally). Copernicus, by fostering the development of this market, contributes to the associated job creation.
Environmental	• Copernicus helps to monitor biomass; it also helps to **reduce the emissions of greenhouse gases** by triggering the production of biomass.
Strategic	• Copernicus contributes to the increase of production of renewable energies by making them more cost-efficient, thus contributing to **reducing the dependence to fossil fuels**.

Figure 113 - Synthesis of Copernicus impacts – Renewable energies (source: PwC-Strategy& analysis)

[337] *EC-ESA factsheet, 2015. Sentinel-4, Copernicus geostationary atmospheric mission.*

[338] *Copernicus, 2013. Highlighting Earth's solar resources from space. Prepared by ESA and the European Commission. October 2013. No. 4.*

Voice of Copernicus' users[339]: SWOT

STRENGHTS

- McClear service is simple to use.
- Copernicus provides the right data for PV production forecasting. The data is also already computed and corrected.
- The EO data are homogeneous and do not depend on the type of sensors on site. They also are stable in time.

OPPORTUNITIES

- EO-based forecasts have more value-added in isolated zones such as islands.
- Offshore wind farms is a mature source of energy so now the competition is on the optimization of the energy production, for which EO data can be of a great help.
- Biomass energy producers are increasingly required to report on the way they manage their forest of biomass and have to trace their biomass.

WEAKNESSES

- Some research centers are not yet completely sure of the continuity of Copernicus and spend time and money to archive all the Sentinel-1 data. For the area they are working on.
- The EO data are less accurate than sensors.
- McClear and water vapour are not provided for free in near real time.

THREATS

- Airborne data is also used for monitoring solar and wind farms.

[339] *PwC-STRATEGY& analysis, on the basis of interviews conducted in 2016 (cf detailed list of interviewees in the appendices)*

Policy recommendations to foster Renewable energies through Copernicus

Strategic pillar	***Sectoral recommendations for policy action***	***Priority level***
***Pillar I*: Ensure access to data**	***#RE-1 – Make the aerosol forecasts as easy to access as McClear*** The data should be made as available as possible for all kinds of users. Indeed, it can be fastidious for users to understand the catalogue of data and to download the right data. In particular, it is fastidious to access aerosol forecasts. However, McClear is quite easy to access.	3
***Pillar I*: Ensure access to data**	***#RE-2 – Make water vapour data available in near real time*** Today the water vapour is not available in real time in CAMS so McClear neither, it is available only sold by ECMWF. Not having the real time data makes the production of PV forecasts harder.	3
***Pillar II*: Support innovation**	***#RE-3 – Make available Sentinel-1 wind maps*** Producing wind maps is time consuming for VAS companies and research centres. It would make them save time if Copernicus could deliver ready-made wind maps. Wind maps are useful for forecasting wind turbines electricity production and making them available could enable the VAS companies to focus on the development of new value-added services.	2
***Pillar III*: Increase awareness**	***#RE-4 – Raise awareness of the impact of EO applications for wind farms*** Today, wind farm developers have a cultural barrier for adopting EO products and integrating them in their models whereas it has been proven that it improves the results. A communication campaign on the topic could foster the adoption of EO products among this type of actors.	1

Air quality

Key domain characteristics and specificities
➢ **EO data on atmospheric composition has been introduced in air quality analysis models only recently; these models are historically based on meteorological data, air composition statistical data and measurements** ➢ **Intermediate users are mainly meteorological and environmental agencies or publicly-funded organisations such as associations; however, an increasing number of VAS companies are entering the market with air forecasting products** ➢ **The end users are mainly local authorities that want to monitor the air quality on their territory and implement the right policies about traffic regulation, industries, etc. and individuals who want to be aware of the risks related to air pollution** ➢ **The potential for development of a commercial market of EO-based products and services for air quality analysis is for now limited in most of the Western countries: this is due to the fact that the needs of end users are already addressed satisfactorily by the public sector and individuals are generally not willing to pay for information on air quality** ➢ **The Copernicus Atmosphere Monitoring Service (CAMS), providing different reanalyses and near-real time analyses and forecasts related to the atmosphere composition, is the most used Copernicus product in the field of air quality analysis**

Scope/boundary of the study analysis

In this report the air quality value chain is intended to include issues and applications pertaining the monitoring of "the **atmospheric composition of gases and particulates near the Earth's surface**"[340]. This translates into the study of the troposphere and a part of the stratosphere, which are the lowest layers of the atmosphere as we can see on the figure below. The air composition of this part of the atmosphere depends on local contributions (emissions of pollutants), chemistry, and transport processes; it is highly variable in space and time.

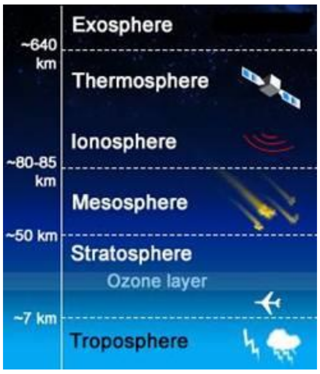


Figure 114 - Structure of the atmosphere (Source: American Association for Science and Technology)[341]

The lowest troposphere is where we live and where most of the pollution is emitted, we will mainly focus on this part of the atmosphere in this analysis as it is the most impactful at local and urban scales. The long-range transboundary air pollutants fluxes which mainly take place in the upper parts of the troposphere also have an impact on local air quality. The pollution in the highest part of the troposphere and the lowest part of the stratosphere comes in particular from aircraft traffic which takes place in these areas and is less impactful at a local scale.

Additional space-enabled applications focussing on the highest parts of the atmosphere do exist (for example, the ozone layer is observed through satellite data since the 1970's), but are not included in the scope of this analysis as it relates to other measurement tools, applications and actors than ground-level air composition analysis. Moreover, the study of the ozone layer and above is usually not considered in the scope of air quality. Indoor air

[340] *Miguel-Lago, M.. 2015.* Monitor air quality & emissions. *[ONLINE] Available at: https://earsc-portal.eu/pages/viewpage.action?pageId=16549044. [Accessed 19 May 2016].*
[341] *American Association for Science and Technology. 2016. Revealing the Cause of Global Climate Change from the Formation and Evolution of Atmosphere. [ONLINE] Available at: http://article.aascit.org/file/html/8990746.html. [Accessed 19 June 2016].*

quality is also out of the scope of this study as EO is not adapted to monitor it and that it corresponds to another system of actors and applications than the ambient air quality.

Taxonomy and definitions

Main definitions related to the air quality value chain	
Air pollution	Air pollution is defined as "the introduction by man, directly or indirectly, of substances or energy into the air resulting in deleterious effects of such nature as to endanger human health, harm living resources and ecosystems and material property and impair or interfere with amenities and other legitimate uses of the environment, and "air pollutants" shall be construed accordingly"[342].
Transboundary air pollution	Transboundary air pollution relates to airborne contaminants which cross geopolitical boundaries or migrate across several geographic zones, even if the physical distance to the boundary from the emitting pollutant source is quite short. Pollutants emitted from natural or anthropogenic sources to the atmosphere may be advected over distances of several hundreds of kilometres to thousands of kilometres.[343]

Value chain description

Overview of industry/domain

Air pollution is among the major challenges of the 21st century, having an **unprecedented impact on human health, climate and ecosystems**. It is the only environmental risk that is shared by the entirety of the world population, as the pollution circulates over the globe. **In 2013 around 5.5 million people died as a result of air pollution**[344]. Lower income countries and in particular, South East Asian and Western Pacific regions are the most affected areas[345]. In particular, in China and in India, less than 1% of the population lives in areas meeting World Health Organisation (WHO)'s guidelines[346]. Moreover, the increasing concentration of greenhouse gases and the cooling effect of aerosol (by reducing incoming sunlight) are believed to be prominent drivers of climate change, although the extent of their impact is still uncertain[347].

The economic impact associated to air pollution is significant. **In 2010, it represented EUR 15 billion from lost work days, EUR 4 billion from healthcare costs, EUR 3 billion from crop yield loss and EUR 1 billion from damage to buildings in the EU alone**[348].

As early as 2008, the European Court of Justice confirmed in a landmark decision that all EU citizens have the enforceable "right to clean air", which means that people exposed to air pollution may demand that their municipal authorities build an action plan. The Air Quality Framework Directive (2008/50/EG) sets limit values for ambient air pollution and explains which measures should be taken in case the limit values have been exceeded[349].

For taking the right actions to mitigate air pollution it is important to understand where it stems from. The sources of air pollution are numerous as we can see on Figure 115 and include road and other kinds of transports, gas heating, coal combustion, construction, agriculture, etc. Air pollution is mainly created by local activities and

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[342] *United Nations, 1979. Convention on long-range transboundary air pollution.*
[343] *Di Giovanni, F:, Fellin, P., 2006. Transboundary air pollution. Environmental Monitoring, [Eds.Hilary I. Inyang, John L. Daniels], in Encyclopedia of Life Support Systems (EOLSS), Developed under the Auspices of the UNESCO, Eolss Publishers, Oxford, UK, [http://www.eolss.net].*
[344] *Global Burden of Disease, 2015. Ambient Air Pollution Exposure Estimation for the Global Burden of Disease 2013. Environmental science and Technology, 50(1), 79–88.*
[345] *World Health Organization, 2014. Burden of disease from the joint effects of Household and Ambient Air Pollution for 2012.*
[346] *Global Burden of Disease, 2015. Ambient Air Pollution Exposure Estimation for the Global Burden of Disease 2013. Environmental science and Technology, 50(1), 79–88.*
[347] *European Environment Agency, 2015. Air quality in Europe - 2015 report. No 5/2015*
[348] *European Environment Agency, 2015. Air quality in Europe - 2015 report. No 5/2015*
[349] *Clean Air. LIFE+ Clean Air – NGOs take action to clean up the air. [ONLINE] Available at: http://legal.cleanair-europe.org/legal/. [Accessed 15 June 2016].*

natural phenomenon but can also be brought by transboundary fluxes over thousands of kilometres such as dust outbreaks coming from African and Arabian deserts over Beirut[350].

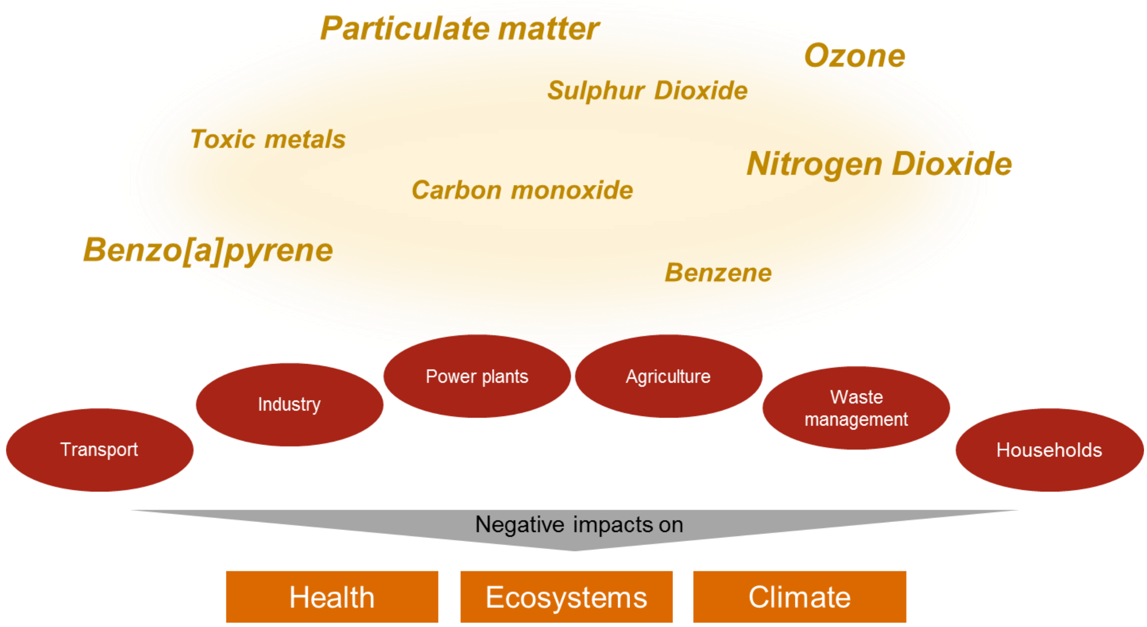

Figure 115 - Overview of anthropogenic air pollution factors and their main negative impacts (Source: EEA[351])

Strategies for reducing air pollution both rely on mitigation, by reducing pollutants emissions, and adaptation, by tackling exposure, vulnerability and impacts. Different regulations, standards and international targets are setting a framework to contain emissions of pollutants in the atmosphere. The WHO and other organisations such as the European Union set limit values for specific gases and for particulate matters. The COP 21, i.e. the 2015 United Nations Climate Change Conference which negotiated a global agreement on the reduction of Climate Change, has also resulted in non-constraining greenhouse gases (GHG) reductions target by country.

While over the past couple of decades the EU air quality policy has made important progress in curbing harmful pollutants, EU Member States still struggle to comply with these limit values. This is particularly the case for particulate matter, nitrogen dioxide, and ozone, which have been demonstrated to have a serious impact on health. About one third of the European Union's urban population is exposed to air pollution above EU limit values[352].

The **systems measuring air quality, when they exist, are very heterogeneous** both in the way the estimation is produced (the chosen type of data and models, etc.) and the way it is organised at the national and local scale (left up to the private sector or to the public sector, etc.). To monitor air quality, both the emissions and the concentrations have to be taken into account. Today, emission inventories that have to be reported to monitor the international targets are built based on declarative part (industries, etc.) and an estimated part (road traffic, energy consumption, burnt wood, etc.). It is important to have reliable measurements of air quality in order to reach the targets, assess the efficiency of policies, identify the main sources of pollution and inform the population.

Obtaining accurate measurement of the air composition is not sufficient to assess the overall air quality, to understand the level of risk associated with the measured values and to communicate the risk to the general public**.** Thus, indicators combining different parameters have been created which are called **Air Quality Indexes (AQI)**: they take into account the quantities of pollutants in the air but they can also take into account the temperature, the humidity or the pressure. For example, the AQI used in Europe is the Common Air Quality Index (CAQI) developed by Citeair, and in India the Ministry for Environment, Forest and Climate Change launched in 2014 the National Air Quality Index.

[350] A Saliba, N., 2013. Atmospheric markers of African and Arabian dust in an urban eastern Mediterranean environment, Beirut, Lebanon. Journal of Aerosol Science. Issue 66. 187-192.
[351] European Environment Agency, 2015. Air quality in Europe - 2015 report. No 5/2015
[352] Joint Research Centre (JRC), 2015. Science for environmental sustainability, JRC thematic report.

Value chain characterization from an EO data usage standpoint

Current use of EO data

ENVISAT is the only satellite which successfully achieved to provide relevant information for the monitoring of air quality in the beginning of 2000's[353]. EO satellites today are capable of measuring emissions of carbon, ozone, and numerous other air pollutants including particulate matter including dust, smoke, and pollen.

A radiation received by a satellite's sensor has gone through the atmosphere which interacts with the radiation in two ways:

- **Absorption of the radiation** by the gas molecules which impacts the radiation's wavelength in a way specific to each gas;
- **Scattering of the radiation** that hits the gas molecule or the particulate (aerosols); this does not modify the radiation's wavelength but impacts its direction of propagation. For example, an extreme case of diffusion is a cloud which reflects a large part of the radiations[354].

The EO images provide timely, spatially explicit, large scale information on distribution in a cost-effective manner. They do not have the same resolution depending on the type of emissions processes. For example, the available EO data on ammoniac, linked to farming activities, has a rather low resolution.

There are two main purposes for EO-based air quality monitoring products and services. On one side, such products contribute to policy and regulations: one example is the Copernicus Atmosphere Monitoring Service (CAMS), providing continuous data and information on atmospheric composition, which enables to compare the air quality between the different European countries, to set limit values and control whether they are met. On the other side, many **applications focus on general population health monitoring**: examples are support to situations in which there are pollution peaks, or support to data analyses to observe relations between life expectancy and air quality.

These kinds of applications are based on air quality hindcasting, nowcasting and forecasting for which EO data is very useful. Specific examples include:

- In North Rhine-Westphalia, the re-analysis of past air quality data has been a key tool for the local authorities. The region accounts for 28% of Germany's nitrogen dioxide emissions and 50% of industrial fine particle emissions. Air pollution thus represents a major health threat for this region having a high population density. However, any EU Member State that violates the European air quality directive should be subject to sanctions. If until recently, the German Department for Air Quality had relied on ground measurements, **EO data enabled the analysis of supra-regional pollution episodes and to prove that in some cases North Rhine-Westphalia was not responsible for having exceeded the limit values.**[355] **High level movements of pollutants can only be measured by satellite.**
- During the episode of high sulphur dioxide in Paris after the eruption of the Icelandic Eyjafjöll volcano in 2010, EO data has been used to understand whether restrict road traffic would have a significant impact on air quality (it turned out that it was not the case). **This episode showed that forecasting quality in case of air pollution peaks and elaborating scenarios provided effective support to critical decision-making.**
- On the private side, **Plume Labs**, a start-up based in France, offers **near-real time information on air quality** in the main cities over the world. The company provides the general public with detailed air pollution alerts via email, mobile phone text messages, or via websites. However, this Plume Labs product is a loss leader, indeed, most of other now-casting initiatives are mandated by public authorities. For example, AirTEXT which forecasts air quality over London and some other towns in the UK, and sends air quality alert messages to the citizens, is funded by local authorities and developed by the start-up **CERC**.

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[353] *Peuch, V.-M., (2015). Prévoir la qualité de l'air : le programme européen Copernicus.* In Prévoir la qualité de l'air : le programme européen Copernicus2. *Paris, 04/11/2015.*
[354] *Kergomard, C., 2002. La télédétection aérospatiale: une introduction. Ecole Normale Supérieure Paris.*
[355] *Eurisy. 2014.* North Rhine-Westphalia: monitoring air quality. *[ONLINE] Available at:* http://www.eurisy.org/good-practice-north-rhinewestphalias-environment-agency-monitoring-air-quality-_77. *[Accessed 22 May 2016].*

Type of applications	End users	Benefits
• Urban air nowcasting and forecasting	• Citizens • Municipalities	• Decision input for local public health and climate change policies • Transparency with the citizens
• Pollutant fluxes tracking	• Public authorities • Research centers	• Identify the polluters • Scientific research
• Local scale air quality analysis	• Companies such as industries, airports, waste amnagement companies etc.	• Local envionmental impact assessment
• Hot spots detection	• Institutions	• Identify the polluters • Identify the critical areas in a region

Figure 116 - Summary of main EO applications in Air quality (Source: PwC-Strategy& analysis)

Market structure and trends

The commercial market for air quality applications is rather small. **In 2012**, the EO downstream market in the field of air quality was estimated at **EUR 13.36 million**[356]**. In 2015**, it is estimated at **EUR 1.82 million**[357]**.** About **80% of the revenues in the air quality market come from European sales** but the VAS companies consider that their **main opportunities are in developing countries.**

(M EUROS)	Overall EO downstream market[358]	% of the overall market for air quality only[359]	EO downstream revenues for air quality
2012	786	1.70%	13.36
2015	911	0.20%	1.82

Table 58 - EO revenues for air quality (source: PwC-Strategy& analysis)

According to EARSC 2013 Industry Survey, Atmosphere is the **Copernicus service holding the least interest in terms of business** for the companies interviewed[360]. There is a number of reasons for this:

- **Private target end users are not willing to pay for such information**, and the users that are willing to pay need much customised measurements that require dedicated sensors rather than satellite data;
- Key end users are **environmental agencies and municipalities but they do not have the budget** to pay for commercial products, thus relying on publicly-funded ones;
- **In most of the countries, in particular in the developed countries, the public sector traditionally covers the air quality analysis**. This is particularly the case in France, where market is difficult to enter as today, dedicated public-funded associations, the "Associations Agréées de Surveillance de la Qualité de l'Air" (AASQA) cover the whole territory. It happens that they buy services from SMEs to support their air quality forecasting activities but still, there is little room for VAS companies;

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[356] *EARSC, 2013. Comprehensive Industry Survey. A Study into the state and health of the European EO Services Industry. 2012 industrial Survey. Under an assignment of the European Space Agency.*
[357] *EARSC, 2015. EO Services Industry. A Survey into the state and health of the European EO Services Industry. Under an assignment of the European Space Agency.*
[358] *EARSC, 2015. EO Services Industry. A Survey into the state and health of the European EO Services Industry. Under an assignment of the European Space Agency*
[359] *EARSC, 2015. EO Services Industry. A Survey into the state and health of the European EO Services Industry. Under an assignment of the European Space Agency*
[360] *EARSC, 2013. Comprehensive Industry Survey. A Study into the state and health of the European EO Services Industry. 2012 industrial Survey. Under an assignment of the European Space Agency.*

- **Numerous air quality analysis numerical models were already very performant, so adding Copernicus data has only slightly improved their accuracy.** This is for example the case of AirTEXT in the UK or of PREV'AIR, the historical national model in France.

However, the **air quality monitoring market is expected to grow at a rate of 8.5% per annum from 2016 to 2021**[361]. This means that the market sizes of the EO products in the field of air quality for 2012 and 2015 have to be treated with caution, they are based on a survey which may not be exhaustive. In addition, according to our stakeholder consultation the market should definitely be growing in the coming years and the main business **opportunities lie in specific markets** (tourism, real estate agencies, etc.) for which customised in situ data is used to complete satellite data.

There is also an increasing demand for air quality analysis at the scale of individuals. Applications to provide such services are currently being developed but do not always rely on EO data. For example, initiatives under development that we can consider as rival to EO-based applications include the following:

- Research is being done on how to analyse the quality of the air breathed by a specific person based on the different activities performed within a day and on the values measured for each type of environment where the person has been;
- The second method is the one on which most of the actors are working, and consists in developing different kinds of **individual sensors on connected objects** (on phones, on watches, etc.) which could provide in an instant very customised analysis on the air quality. Such very small scale sensors could also be used by real estate agencies to provide precise information on their properties. **However, today the quality of such sensors is not good enough to take daily decisions based on it.**

Some towns have made the choice to set sensors in strategic places to get very accurate and localised in situ data and in some cases produce forecasts at the scale of a street. Often the collected data is nested in an air quality analysis model using EO data. For instance, in Copenhagen, air quality is analysed from each side of one of the city's main roads, and sometimes differences between the two sides of the road are reported.
One of the possible future applications of EO data will be to **trace the pollutant fluxes.** However, the geographic precision of the emissions is yet rather low, so far from a level that could be used to control the polluters and get data with a legal value. This would require significant improvements in re-analysis.

Key Drivers	Key Obstacles
	Most of the **end users are not willing to pay for information on air quality**
There is an **increasing demand for air quality applications for cities in developing countries** and EO data is increasingly used for such applications as it improves the results of the analyses	There is an **increasing demand for very local and customised air quality applications, at the scale of an individual, that can be met only by very sensitive sensors**, currently under development, on connected objects for example, and the EO data cannot be used for such applications
There is an **increasing demand for air quality information at a street level**, this is reached by extrapolating the information of in situ sensors with EO data	Key users are **environmental agencies and municipalities but such actors do not have the budget** to pay for air quality monitoring products and there are no legal obligations for them to procure air quality monitoring data
There are increasing reporting obligations because of the **strengthening of regulations on air quality monitoring**	In the most developed countries, such as in the EU member states, the **public sector already covers the field of air quality analysis** leaving little room for private actors to enter the market with commercial products

Table 59 - Main key drivers and obstacles in the Air quality EO market (Source: PwC-Strategy& analysis)

[361] *Marketsandmarkets, 2015. Air Quality Monitoring Market by Product (Fixed Gas, Portable, Dust & Particulate Monitor, AQM Station), Pollutant (Chemical, Physical, Biological), End User (Government, Commercial & Residential, Petrochemical, Pharmaceutical) - Forecast to 2021*

Main players (examples) globally and in Europe

The intermediate users in the field of atmosphere are mainly public actors[362]. In particular **national and international meteorological agencies** (Meteo France, Finnish Meteorological Institute (FMI), European Centre for Medium-Range Weather Forecasts (ECMWF), the World Meteorological Organisation that federates all the 191 national meteorological services in the world, etc.) acquire the data, develop their models, process data, perform research and sometimes even have their own sensors. The ECMWF holds a specific role as the European Commission outsources to the organisation the coordination of CAMS, but they also sell their own air quality EO-based products such as near-real time vapour data. Other kinds of **public-funded organisations** also process and interpret the data for public authorities; it is for example the case of the Institut National de l'EnviRonnement Industriel et des RisqueS (INERIS) who is in charge of the French PREV'AIR air quality model.

The FMI is an interesting example to understand the relations between the various kinds of players. The FMI participates in CAMS regional air quality forecasting and in particular, its products are used to assess the quality of CAMS data. In this framework, its model produces daily air quality forecasts and hindcasts, interim and verified reanalysis. Its primary users are CAMS itself, then, through the CAMS infrastructure, its products are available for a wide range of users and finally, several users directly connect to the FMI's website to download CAMS-related products. Some examples of users that directly access the products through the FMI are: institutional users such as the Bulgarian Meteorological Services which download SILAM-related products (SILAM is a model which forecasts the spatial dispersion and the chemical transformations of gas). Indeed, the Lithuanian Environment Protection Agency uses FMI's forecasts for their national forecasts, the Helsinki Metropolitan Area Council uses both FMI's forecasts and reanalysis in their daily activity, and, the last example is the general public that gets access to animated pictures showing the pollution in Europe and, as a downstream service from CAMS, regional air quality forecasts.

There are only few private players developing air quality applications. Some examples of VAS companies include:

- **Numtech** is a company focusing on the air quality analysis for municipalities through their product Urban Air and for industries with their product Plum'Air (more details on their activities can be found in the case study below);
- **TNO** is a company of 2500 people working in many fields related to innovation, a unit of the company provides a wide range of air quality products for some of them based on EO;
- **ARIA Technologies**, who offers a wide range of services related to air quality at different scales and who sells regional air pollution dispersion forecasts to private companies such as TOTAL;
- **ACRI ST**, a SME specialised in various EO applications among which air quality modelling.

Most of these VAS companies are based in Western countries but they are often trying to enter other continents markets such as North Africa, Middle East or Asia.

Data flow along the value chain

Data collection and processing platforms

The **in situ air composition data** in use includes measurements provided by ground sensors, air balloons, etc. This type of data comes from crowd-sourced air quality sensors networks, from AirBase, a European air quality data base maintained by the European Environment Agency, from associations such as AASQA in France, etc.

The **EO data on air composition** mainly comes from many space programme such as ENVISAT, EUMETSAT, Aura and Terra, or the Japanese or Chinese space agencies.

For applications in urban areas, some data can be provided by local authorities or by public operators, such as information on **road traffic or the geography of a city**. Some information on **land cover and land use** can also come from Copernicus, from other satellite data, from Geographic Institutes (e.g. Institut Géographique National (IGN), etc.).

In the field of air quality, Copernicus' most used service is the **CAMS**. The service provides several products, the main one being the consolidated in situ measurements provided by the countries around the world. CAMS also offers EO raw data such as water vapour, dust and pollen. The Copernicus Land Monitoring Service is also used for its land cover and land use products. Today, the operational Sentinels do not provide the relevant data for air quality analysis. However, Sentinel-3, 4 and 5p will provide relevant data.

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[362] *EARSC, 2015. A survey into the State and Health of the European EO Services Industry. Prepared by EARSC under assignment from ESA, September 2015.*

	Ground monitors	EO data	Statistical data	Other type of data	CAMS
Data source	• Air quality analysis stations • Balloons	• NASA • National Oceanic and Atmospheric Administration • Etc.	• EO data • Ground-based data	• Data to be collected towards different types of stakeholders such as local authorities • EMEP/EEA • EPA/US	• Global forecasts • Regional forecasts
Type of data	They take measures of a series of reference gases and aerosols.	• Nitrogene dioxide • Sulfur dioxide • Ammonia • Carbon monoxide • Some volatile organic compounds • Aerosol optical depth • Surface particulate matter • Land cover and land use	• Statistical data on past air quality	• Road traffic • Geography of a city • Inventories of emissions	• Air quality forecasts and now casts • Raw data on aerosols (water vapour, dust. And pollen)
Data value added	• Accurate and reliable • Near-real time data	• Stable in time • Covers the planet • Gives indications on the altitude • Enables to track tranboundary fluxes • Near real time data • Hot spot detection	• Enables to do re-analysis for research or to integrate as input in the ait quality forceasting models	• Inputs for models	• Reliable integrated model • Integrates long distances pollutants fluxes in the analyses

Figure 117 - Different sources and types of data used for analysing air quality and their value added (Source: PwC-Strategy& analysis)

Outsourced and in-house capabilities

Regarding urban air quality, the air quality monitoring capability is in general rather held by the public sector in Western countries and by the private sector in the developing countries, with a few nuances. Below are some examples:

- In France, the French agency INERIS is the one analysing CAMS data and other background air quality sources and sends its results to the public funded associations AASQA. There is a bit more than one AASQA per region and each of them is dedicated to producing air quality forecasts for its reference territory on behalf of the Ministry of Ecology. The AASQA are quite autonomous in their working methods and some of them outsource some parts of their activities (for example the start-up Numtech sells its system to several AASQAs) to private actors, however the trend is moving towards more internalisation.
- However, in the UK, the municipalities are directly responsible for monitoring the air quality over their town, so they outsource air quality analysis to private actors such as the start-up CERC who runs AirText for the city of London.
- In Morocco, the city of Casablanca has outsourced the air quality analysis activities to the company Numtech.
- In China, the government is having in-house air quality analysis activities but collaborates with private and foreign actors for developing its models.

The industrials usually outsource the air quality analysis activities to monitor their environmental impact and achievement of the regulatory constraints.

Development of value-added software, products and applications

Analysing air quality requires using numerical models and the EO data is one of the inputs entered in such models. As detailed in Figure 118, there are several methods to combine the different sources of data.

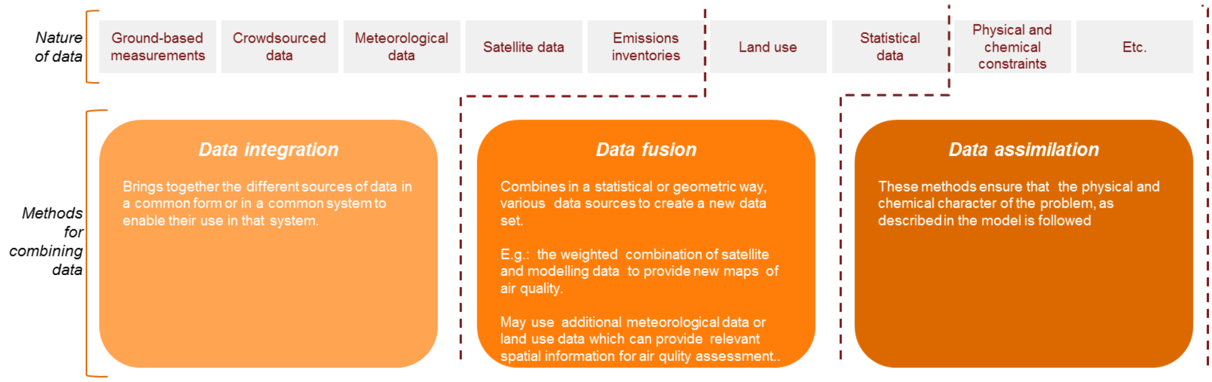

Figure 118 - The different families of methods for combining data and producing air quality analyses and forecasts (Source: Denby, Spangl)[363]

For example, CAMS uses a data assimilation method, which is based on numerical models in which EO data, in situ data, and meteorological data can be injected. Different models do not obtain exactly the same results with the same input data. Hence, several models are used in parallel in order to reduce the margin of error. CAMS European service uses 7 different models whereas the global service is based on only one. The 7 models used by CAMS include historical models such as the French models CHIMERE and MOCAGE.

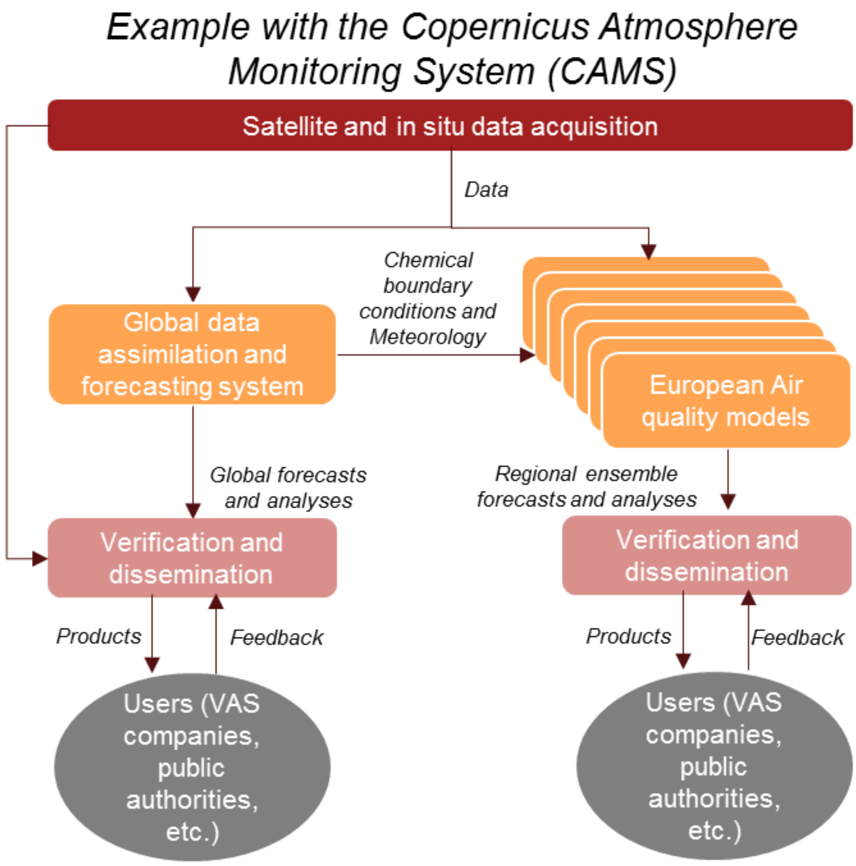

Figure 119 - Supply chain of air quality forecast production based on the example of CAMS global and regional models (Source: V. Puech)

Land cover and land use data is often used to estimate air quality at a small scale, such as in a town. For example, in situ air quality measurements are extrapolated based on pollution sources, such as road traffic, identified thanks to EO data.

There are various challenges linked to the use of EO data for analysing air quality. First, the resolution is often too low to use EO data alone. For example, the figure below compares the spatial scale of MACC-II (precursor of

[363] *Denby, B., Spangl, W., 2010. The combined use of models and monitoring for applications related to the European air quality directive: a working sub-group of FAIRMODE. NILU and Federal Environment Agency (Austria).*

CAMS, using inter alia EO data) global and regional models with the spatial scale of in situ data. We can see that MACC-II unit, corresponding to the red squares for the Global service and to the blue squares for the Regional service are bigger than the size of an average town. The resolution can be used for having a global overview of the air quality in an area but is not high enough to monitor air quality at district or street level when it is not combined to other kinds of data. However, within a town, the air quality can be very different depending on the position, and it is this level of details that is interesting for municipalities and citizens.

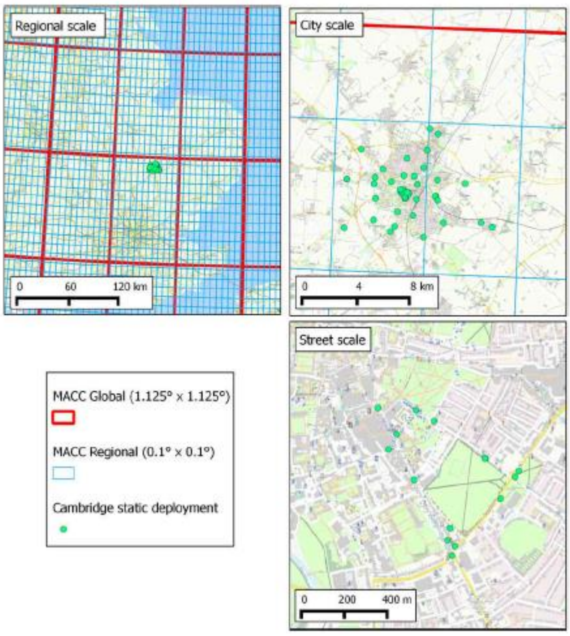

Figure 120 - Illustration of significant differences in spatial scale between MACC Global, MACC regional and in situ data (Source: NILU)[364]

Second, EO data can be hampered by gaps and discontinuities. For example, the figure below shows both gaps between the swaths of the satellite platforms as well as missing data points due to clouds and/or measurement issues within each swath. The different methods for combining data (data integration, fusion and assimilation) add value to the observations by filling in the spatial-temporal gaps in observations.

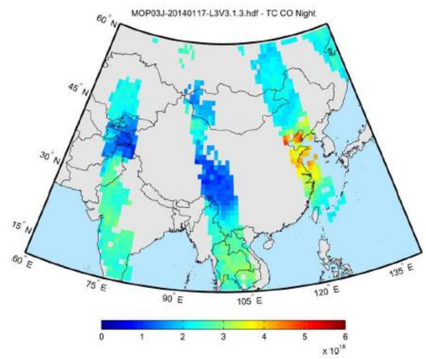

Figure 121 - Plot representing typical data gaps in satellite observations of tropospheric composition, illustrated using night time total column carbon monoxide retrieved over Asia using data from the MOPITT instrument on 17 January 2014 (Source: NILU) [365]

The initiative AirNow, a public-funded initiative to monitor the Air Quality Index over North America, well illustrates the importance of combining data. Indeed, integrating EO data in AirNow has enabled to fill in the gaps between the monitor stations that are sometimes far from each other. On the figure below, we can see how fusing the routine ground-based measurements with satellite-based estimates for PM2.5 has improved the accuracy of the service. Indeed, in situ data filled the gaps and calibrated the results obtained with the EO data. **EO data has expanded AirNow data coverage and enhanced the accuracy of the analysis.**

[364] *Lahoz, W.A., Schneider, P., 2014. Data assimilation: making sense of Earth Observation. Frontiers in Environmental Science. Doi: 10.3389/fenvs.2014.00016.*
[365] *Lahoz, W.A., Schneider, P., 2014. Data assimilation: making sense of Earth Observation. Frontiers in Environmental Science. Doi: 10.3389/fenvs.2014.00016.*

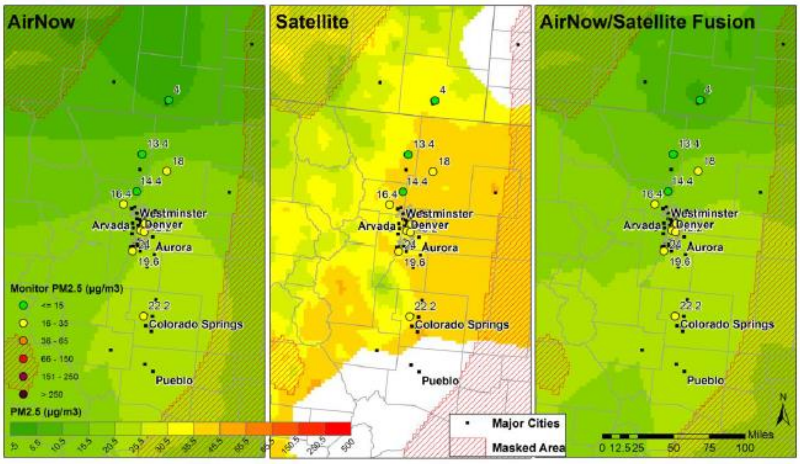

Figure 122 - Example of the fusion of extrapolated in situ data within Airnow and satellite data for analysing ground concentrations of PM2.5 (Source: JAXA)[366]

Models producing different levels of data (for example regional, local and street scales) are often nested in order to be able to zoom in and zoom out over the same area. For example, the FMI uses Copernicus for forecasting over Europe; then they process this data into different systems in order to get different levels of view until they reach the right precision to get information at the scale of Helsinki streets. However, this kind of models can be too expensive for some municipalities in particular in a period of cost-cutting.

End users

Air quality forecasting provides key tools for **public authorities** (international organisations, national governments and in particular municipalities) as it enables them to:

- assess the impact of several air pollution mitigation scenarios and identify the best measure to adopt to solve an air pollution crisis or prevent major air pollution episodes;
- target actions that have a real impact and a good cost/benefit ratio on the mid and long term;
- limit the impacts of air pollution by informing the population and thus, reducing their exposition to risks in case of air pollution peak for example.

Individuals want to have information on air quality and are users of specific applications often in the town where they live. For example, in London, the AirTEXT application counts around 15.000 subscribers.

Private companies such as sectoral industry players, airports, waste management companies, consultants with specific expertise or SMEs use air quality forecasts in order to monitor their compliance with the limit values, their negative impact on the environment, on the health of their employees (people living in the surroundings of a plant for example) and on the citizens at large. For example, industrials of all over the world buy NUMTECH's PlumAir (95% of the clients are industrials), a product which help them monitor their impact on air quality at a local level.

Research companies use this information to better understand the climate and past greenhouse gases trends that are used to identify global major drivers, adjust emission projections, evaluate mitigation policies, build several scenarios and assess their impact. For example, the FMI conducts researches on the relation between air quality and climate, the spread and transformation of pollutants.

[366] *JAXA, 2015. Applications of satellite earth observations: serving society, science, & industry. CEOS, JAXA. 2015 edition.*

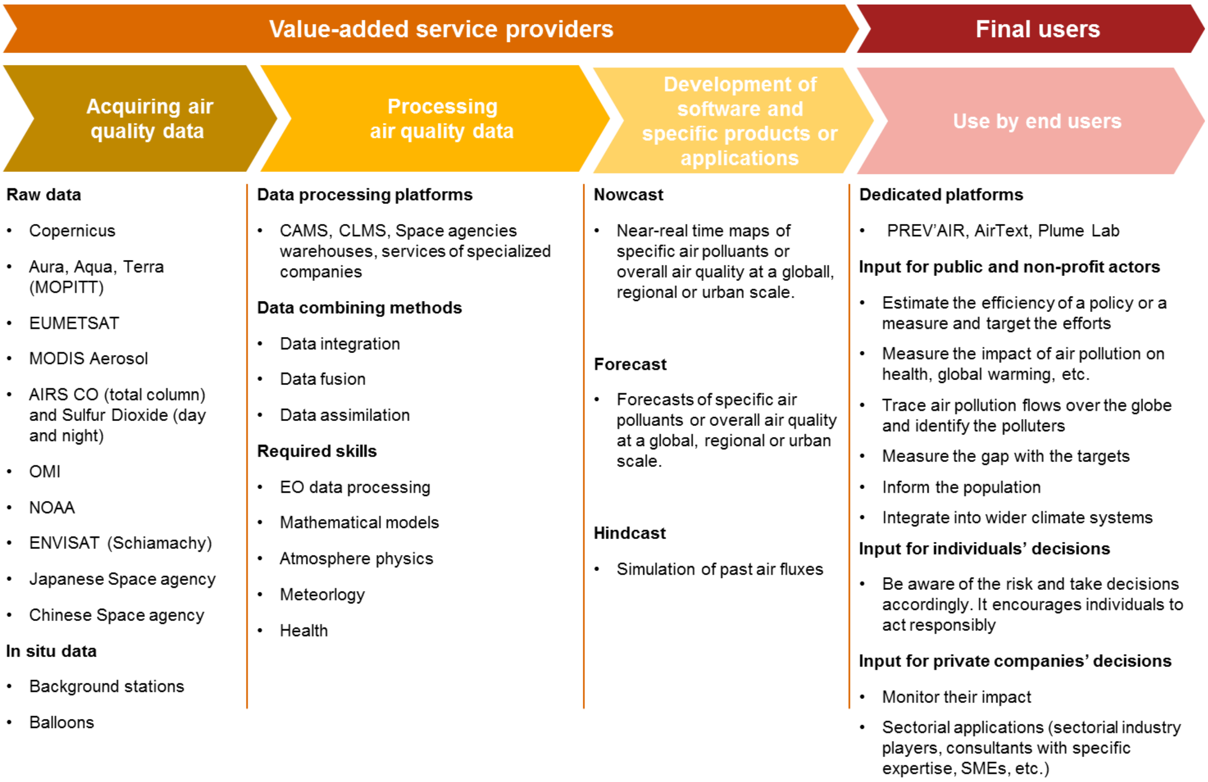

Figure 123 - Data flow along Air quality management value chain (Source: PwC-Strategy& analysis)

Current role of Copernicus

Copernicus services

Most of the intermediate users of the air quality sector do not download directly Sentinel data but use CAMS.

Most CAMS users are based in Europe and are mainly **European-level decision makers** (national governments, regional authorities, environmental institutions). They use the CAMS European scale model for feeding their own models. This is for example the case of the INERIS, which uses CAMS to feed the PREV'AIR model when they consider it useful, or when there is a special event such as a volcano eruption as CAMS is the only way to have a near-real time overview of the phenomenon.

Some **private actors** also use CAMS in the field of air quality, and are **mainly based in Europe.** In the air quality sector, CAMS is mainly used by VAS companies for **developing applications for municipalities to monitor air quality on their territory.** For such applications, **CAMS is used as an entry data in the models in order to take into account the long-range transboundary pollution fluxes which impact the local air quality**. **CAMS is the only tool providing this type of information.** For example, in the AirTEXT initiative, CERC, a small private company which operates it, combines CAMS European scale model with in situ data coming from about 30,000 sources for analysing and forecasting air quality in London down to the street level. CAMS is more particularly used to analyse and forecast the pollution fluxes that come from the rest of Europe over London.

Another application of CAMS for air quality consists in **identifying the hotspots where more accurate data has to be found.** For example, Earth-I produces very precise transportation mappings based on Copernicus data in order to identify the areas with possible poor air quality based on these mappings.

Copernicus is sometimes used as complementary to **local commercial applications such as for controlling the impact of local air quality of a fabric** for example. Industrials who buy such products are companies operating in the sectors of oil & gas, energy, carriers, mining, etc. Indeed, such actors are subject to regulations related to their industrial sites and their objective is to stay under the limit values, for example regarding sulphur dioxide around the refineries.

Copernicus Land Monitoring Service (CLMS), and in particular CORINE Land Cover, can also be used as **entry data in the air quality forecasting models for cities**, providing geographic data, or for **identifying potential pollution sources.**

Copernicus Core Service	Products	Application
Copernicus Atmosphere Monitoring Service	• Daily production of near-real-time analyses and forecasts of global atmospheric composition • Reanalyses providing consistent multi-annual global datasets of atmospheric composition with a frozen model/assimilation system • Daily production of near-real-time European air quality analyses and forecasts with a multi-model ensemble system • Reanalyses providing consistent annual datasets of European air quality with a frozen model/assimilation system, supporting in particular policy applications • Products to support policy users • Greenhouse gas surface flux inversions for CO2, CH4 and N2O, allowing the monitoring of the evolution in time of these fluxes • Climate forcings from aerosols and long-lived (CO2, CH4) and shorter-lived (stratospheric and tropospheric ozone) agents[367]	• Air quality nowcasting, forecasting and reanalysis • Identify hotspots
Copernicus Land Monitoring Service	• Corine Land Cover • Land use	• Air quality nowcasting, forecasting and reanalysis • Identify hotspots

Table 60 - - Main products of the Copernicus services in air quality management (source: atmosphere.copernicus.eu; land.copernicus.eu)

Copernicus data

The next Sentinels will slightly improve the accuracy of the air quality forecasts. In particular, Sentinel-3 will provide additional data on dust aerosol, particulate matters and water vapour, with a good spatial resolution, and Sentinel-4 and 5 will bring additional information on the chemical composition of the troposphere. In particular, Sentinel-5P will be useful to trace pollutants fluxes.

Copernicus socio-economic impact assessment

This impact assessment is based on literature and on the consultation of 14 stakeholders dealing with air quality management, including 6 private actors (4 small and 2 micro companies), 7 public actors (space agencies, meteorological agencies, environment agencies and ministries) and 1 research centre also developing commercial applications. The diversity of the stakeholders consulted ensures a 360 degree view of Copernicus impacts in the air quality sector.

Copernicus current enabled revenues

According to stakeholders consulted in the field of this study, **CAMS regional model is operational, reliable, the quality of the data is good and adapted to the range of pollutants required for monitoring air quality**, and it **is the only integrated system of this kind**. Even if CAMS global model has a lower resolution than the regional model, CAMS has a significant added value in countries where there are no or not highly reliable air quality systems already in place. Stakeholders consulted expressed the fact that it is very valuable to have a reliable and continuous source of data such as CAMS for developing commercial applications (it is less the case for research). Moreover, the migration to Copernicus is considered as rather expensive for such actors so the fact that they have invested in it means that they were really expecting an improvement from the European programme. However, the **air quality models in Europe were already very good before CAMS so the improvement of quality has**

[367] *ECMWF. 2016.* Copernicus Atmosphere Monitoring Service. *[ONLINE] Available at:* *http://www.ecmwf.int/en/about/what-we-do/copernicus/copernicus-atmosphere-monitoring-service. [Accessed 25 July 2016].*

only a limited impact for the European users. Indeed, the quality of the forecasts depends on many data inputs and most of the European actors already have a lot of experience in forecasting.

Today, the intermediate users which use Copernicus use almost exclusively CAMS, but the ECMWF has reported that most of the users were public entities. Under the assumptions that

- 20% of CAMS users – and so 20 % of Copernicus users in the field of air quality – are private actors and 80% are public actors;
- Copernicus users repartition between public and private actors is close to the one of the EO market in the field of air quality because the intermediate actors who use CAMS use it combined with other EO data.
- The possible applications based on CAMS are representative of the applications of the sector;

It can thus be inferred that 20% of the EO intermediate actors in the field of air quality are private and that the other 80% are pubic. Given that the EO downstream market revenues for air quality are estimated in 2015 at EUR 1.82 million (cf. supra 'Market structure and trends'), the EO revenues generated by private actors in the field of air quality in 2015 can then be estimated at EUR 364,000. **The intermediate actors consulted for this study estimated that between 3% and 10% of their revenues associated to air quality products and services can be attributed to Copernicus**[368], leading to total **revenues enabled by Copernicus generated by private actors in the field of air quality estimated to range between EUR 10,900 and EUR 36,400 in 2015.** As the EO market-based calculations constitute the conservative basis for Copernicus benefits, only the 3% share is considered.

The economic benefits from 2016 to 2020 are extrapolated based on the air quality monitoring market, expected to grow at a rate of 8.5% per annum from 2016 to 2021[369], assuming the Copernicus current enabled revenues for air quality generated by VAS actors will grow accordingly.

(M EUROS)	EO downstream market for private intermediate actors in the field of air quality	% of Copernicus enabled revenues (conservative approach)	Copernicus enabled revenues (conservative approach)
2015	0.36	3%	0.01
2020	0.54	3%	0.02

Table 61 - Copernicus current enabled revenues for air quality generated by VAS actors (source: PwC-Strategy& analysis)

A more optimistic approach on the economic impacts of Copernicus consists in considering the wider GIS market as a basis for the intermediate users' benefits. According to Technavio[370], the European GIS data and services market represented EUR 1.34 billion in 2015. Assuming that:

- The share of air quality in the GIS market equals the share of air quality in the EO market - i.e. 0.2% - and that it remains constant until 2020;
- The share of Copernicus in the revenues generated by GIS data and products in the field of air quality is the same as the share of Copernicus in the EO market for air quality monitoring, i.e. 10%. The choice of the highest estimate is justified by the release of new CAMS products which should increase the use of Copernicus in the coming years according to stakeholder consultations;

The total Copernicus-enabled revenues in the field of Air Quality on the GIS market can be estimated to grow from EUR 0.27 million in 2015 up to EUR 0.42 million in 2020.

(M EUROS)	GIS data and services market for air quality monitoring	Copernicus revenues generated by GIS data and services companies (optimistic approach)
2015	2.67	0.27
2020	4.18	0.42

Table 62: Copernicus current enabled revenues for air quality monitoring generated by GIS data and services companies (source: PwC-Strategy& analysis)

[368] *Source : Stakeholder consultation, PwC analysis*

[369] *Marketsandmarkets, 2015. Air Quality Monitoring Market by Product (Fixed Gas, Portable, Dust & Particulate Monitor, AQM Station), Pollutant (Chemical, Physical, Biological), End User (Government, Commercial & Residential, Petrochemical, Pharmaceutical) - Forecast to 2021*

[370] *Technavio, Global GIS market 2016 - 2020*

In the field of air quality most of the **end users** use Copernicus based products for monitoring air quality in order to communicate about air quality and take the right decisions in order to monitor air pollution. The Copernicus products are thus not necessarily those who are most impacted by the cost savings induced by such products. Indeed, reducing pollution has an impact on a wide range of actors. In 2010, it represented EUR 15 billion from lost work days, EUR 4 billion from healthcare costs, EUR 3 billion from crop yield loss and EUR 1 billion from damage to buildings in the EU alone[371]. These figures probably increased since 2010 (because of the demographic growth and the raise of air pollutants emissions) but can still be used to obtain a minimal estimation. Thus, the total costs caused by air pollution in 2016 were at least of EUR 23 billion. At this stage it remains challenging to isolate within these costs the potential savings that could be enabled by Copernicus and the economic impacts considered in this section only include intermediate users benefits.

The Figure 109 sums up the different estimates made on conservative and optimistic assumptions.

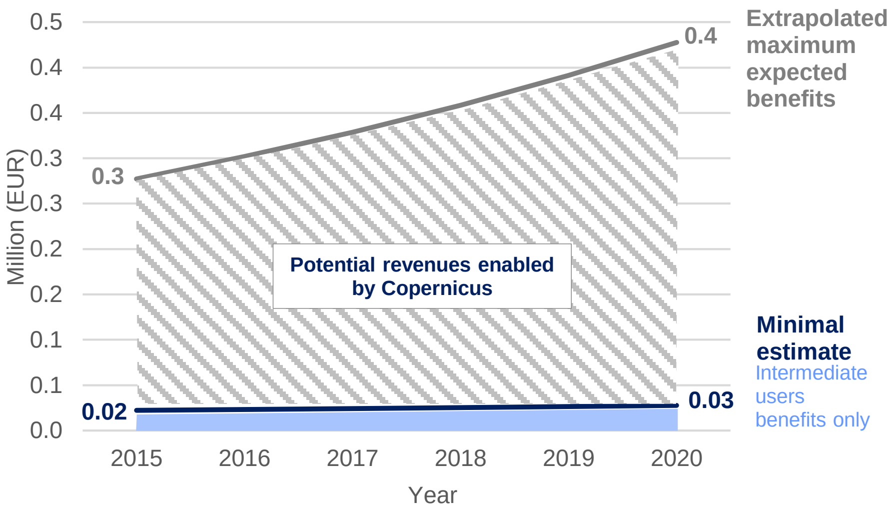

Figure 124: Different scenarios estimates of the revenues generated by Copernicus in the field of air quality (source: PwC-Strategy& analysis)

Over the period 2015 – 2020, Copernicus-enabled revenues in the air quality value chain are forecasted to support a total estimated at **between 1 and 15 person years** within the EO and GIS downstream markets across Europe.

It is assumed that productivity among the intermediate users was the same as for the industries NACE 62.01 and 62.02. The enabled employment estimation method used employment, turnover and GVA data from the Eurostat Structural Business Statistics. The 2020 estimates were based on E3ME growth projections for these variables.

For large scale applications, Copernicus enables the different players to **save time** while they process the data as it offers them the possibility to identify hotspots where to get more accurate data.

For very local applications such as the scale of a fabric, Copernicus has a limited impact because its resolution is too low and pollution fluxes have a small impact on the quality of the data for such small areas. For example, only 2% of the data used by Numtech's PlumAir, a product which analyses air quality for industrials, stem from Copernicus.

Copernicus has a rather strong network effect, in particular for the data providers who have been involved in the collection of the user requirements. Copernicus created many opportunities for the VAS companies operating in air quality, and the different actors share their best practices at Copernicus events. Most of the actors processing CAMS data were already experts of EO data processing or in air quality modelling so they did not need any specific training to handle Copernicus data.

[371] *European Environment Agency, 2015. Air quality in Europe - 2015 report. No 5/2015*

Non-monetary benefits of Copernicus

As explained above, **CAMS improves the accuracy of the air quality forecasts and thus contributes to reducing the air quality risk**. The magnitude by which CAMS improves the quality of the forecasts depends on the model used and expected resolution. For example, in the case of PREV'AIR, CAMS does improve the results but only substantially so its value added is almost negligible (Numtech quantifies the improvement on the quality of the forecast to at least 10%).

For others, better monitoring air quality can **save millions of lives**, reduce diseases such asthma, heart and lung diseases, and help public authorities reduce spending in health or sick-leaves. It would also **reduce the negative impacts on ecosystems, animals and infrastructures which also have a cost for the local authorities.**

Thanks to Copernicus, it is now possible to forecast air quality **all over the world, and in particular in Europe, with a common methodology**. Before Copernicus, most of the European countries managed to establish inventories of emissions on their territory but it was difficult to perform comparison between countries. Thus, Copernicus facilitates the **coordination at the international, European, national and local levels to implement the right policies to fight against air pollution**[372].

Moreover, Copernicus enables having a general qualitative appreciation of the air quality. It provides coverage (with lower resolution) in zones where there is no in situ data. Hence, Copernicus data can be used to **monitor the air quality over areas which did not have any tools to do so and enables to control the data provided by the countries on a declaratory basis.** For example, it turned out that some countries of the Middle-East used to declare wrong locations for some sources of pollution in their national emissions inventories. These locations, mainly border areas, artificially lowered the emissions they are held responsible for. Thanks to Copernicus, it is possible to detect such issues for **more transparency.**

Finally, Copernicus is a **key tool for research on air quality and on climate change**. Indeed, the European programme enables observing major causes for climate change such as human induced changes in greenhouse gases or atmospheric aerosols.

[372] *JRC, 2015. Science for environmental sustainability*. JRC Thematic report, *EUR 27498 EN.*

CASE STUDY

Copernicus for monitoring the air quality in cities down to the street level

Urban Air, an application to monitor air quality at city level

NUMTECH is a French start-up, gathering about 20 people, specialised in the simulation of the atmosphere. One of its three main activities relies in **developing value added services in the field of air quality**. They started using Copernicus three years ago for one of their main products **"Urban Air", which provides high resolution air quality analysis for cities.** Urban Air's clients are municipalities and organisations in charge of analysing air quality (e.g. AASQA in France) which are located all over the world, and especially outside Europe and North America where there are less rival initiatives (including from the public sector). On Figure 125, we can see all the cities in which Urban Air is already operational. On Figure 126, we can see that Urban Air provides air quality forecasts down to the street level with the example of the city of Nancy.

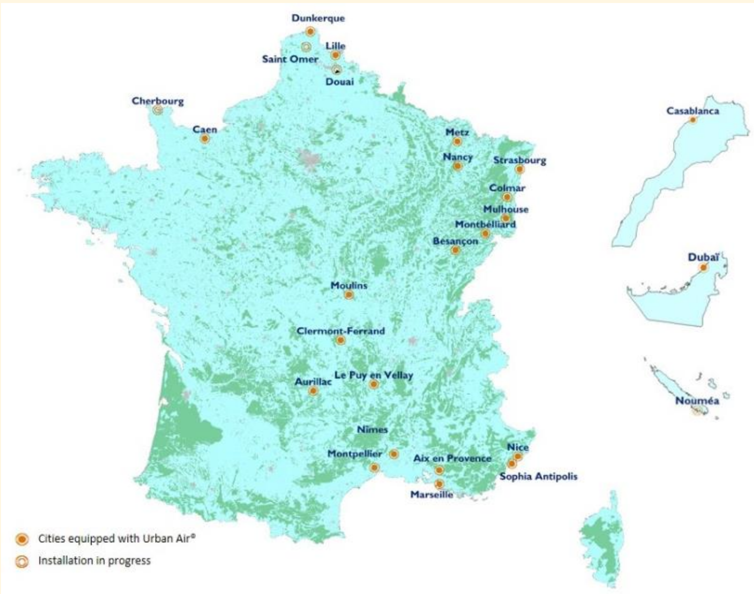

Figure 125 - Cities already equipped with Urban Air (Source: www.numtech.fr)[373]

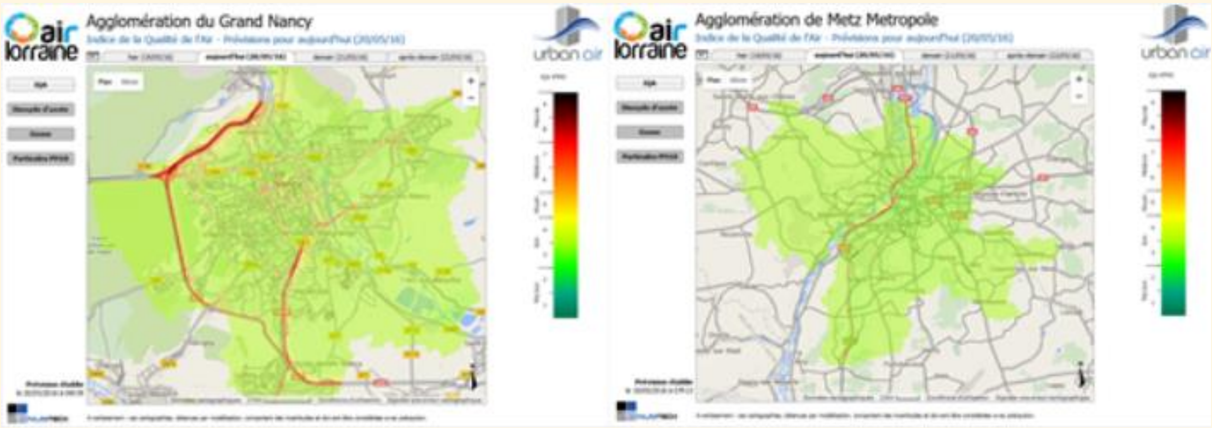

Figure 126 - Example of an operational Urban Air with the city of Nancy (France) (Source www.numtech.fr)[374]

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[373] *NUMTECH. 2016. Urban Air®: air quality forecasting at your fingertips!. [ONLINE] Available at: http://www.numtech.fr/actualites.php?id=172. [Accessed 17 June 2016].*
[374] *NUMTECH. 2016. Urban Air®: air quality forecasting at your fingertips!. [ONLINE] Available at: http://www.numtech.fr/actualites.php?id=172. [Accessed 17 June 2016].*

Urban Air is based on the atmospheric dispersion software ADMS URBAN developed by the SME CERC, a tool able to take into account all urban emissions sources (traffic, industry, residential and tertiary sectors) as well as specific characteristics of pollutants dispersion in urban environment.

Urban Air is being deployed over Paris in 2016, in the frame of a demonstrator project "Env&You" funded by the KIC ICT Labs, a public-funded initiative. This brought together American, Finnish and French initiatives such as Ambientic, CapDigital, Forum Virium Helsinki, TheCivicEngine and Inria. This project aims at developing new services related to environmental data.

Copernicus enabled revenues

One of the issues that NUMTECH has encountered when working for air quality in cities is that **long distance pollutant fluxes have a strong impact on the local air quality**, information which has to be integrated in the models in order to get accurate results. This is where Copernicus is a step change as the **Copernicus Atmospheric Monitoring Service (CAMS) is the only initiative providing this kind of information for free and at a global level.** It is particularly useful for regions such as Eastern Europe, South America, Africa, and Middle East where generally only few surface measurement data are available.

Even if it is at national scale only, air quality data exists in France. The Env&You project is an opportunity to demonstrate the use of CAMS inside Urban Air without the need to interact with third parties, and to demonstrate quality of results compared to similar system over Paris, guaranteeing the system robustness when deployed elsewhere in the world.

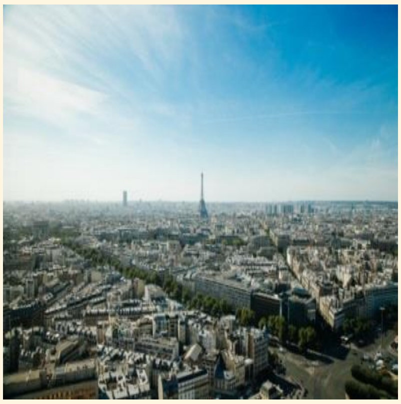

Figure 127 - The "Env&You" project will include Urban Air products to monitor air quality over Paris

The **Copernicus Land Monitoring Service,** both the Global Land Service and the local component, **is also used for Urban Air as entry data of the models. The main strength of Copernicus is its continuity** which makes it reliable for operational projects such as Urban Air.

Copernicus data is combined with meteorological data, data on the geometry of a city (e.g. height and position of the buildings) coming from satellite data or in situ data, and data on emissions which can be provided by municipalities, different operators (e.g. estimation of the road traffic can be provided by both types of actors) or estimated by NUMTECH from data collected from different sources.

About **10% of the data used in Urban Air stem from Copernicus** and accounts for **90% of the data used to analyse the background pollution**, which makes it one of the key inputs of Urban Air. So we can consider that at least 10% of Urban Air's revenues are directly attributable to Copernicus. NUMTECH expects between EUR 1 million and EUR 10 million of annual revenues derived from the Env&You project, so **Copernicus should generate between EUR 100,000 and EUR 1 million of annual revenues on this project.**

Urban Air already existed before Copernicus, but the European programme **facilitated the deployment of the product at a global level** as it enabled NUMTECH to **reach cities where a limited amount of data was available** (e.g. in Morocco and countries of Eastern Europe). In particular, Copernicus enabled to monitor some pollutants such as particulates matter, for which non local emission can largely contribute to local concentrations. **For such pollutants coming from transboundary movements, Copernicus improved the precision of Urban Air by 60%, and we can evaluate an improvement of 10% to 20% to more local pollutants.**

For NUMTECH, the impact of Copernicus will concern two levels:

- On its initial market, Urban Air should enable NUMTECH to **double its turnover in the short term on markets abroad** (minimal estimation), **where the lack of background information on air quality is an obstacle** and so where the analysis of air quality has been made possible thanks to the availability of CAMS.
- The Copernicus programme should generate revenues from **new markets** by selling environmental data via a new start up to different types of clients such as players in the sectors of sports, healthcare, real estate companies, etc. **10 new job positions are being created** for this purpose.

Non-monetary benefits of Copernicus

Urban Air has a **social and environmental impact**: thanks to the information provided by the service, citizens have access to tools in order to take the right decisions to **monitor their everyday health and own impact on their environment.**

The end users of Urban Air are municipalities, and in this case the **city of Paris** for which the tool is of great help to **survey at high resolution the air quality** and to **evaluate impact of urban scenarios on environment**. For example, the City of Paris will use the system to demonstrate the impact of road traffic on air quality and thus be provided with figures to support its urban traffic reduction policy, by comparing two similar days: one normal and one without cars during the day without cars in September 2016.

The transition from a research project to an operational service is key in the development of a project based on Copernicus, so it is important that Copernicus is fully operational and that upgrades are announced sufficiently in advance for them to be able to adapt.

Copernicus projected contribution to the global and European socio-economic impacts

The air quality forecasting market should grow in the next years. First, the penetration rate of the municipalities market should rise. For the moment, local authorities have no legal obligation to monitor air quality at their scale, but it may change in the future, expanding the market for VAS companies. **Then, more actors may want to buy air quality forecasts**. Insurance companies are starting to be interested in large air quality past datasets, in order to reanalyse them and then build their models. Air quality forecasts and Copernicus data on pollen and UV could be used in applications for health by municipalities, citizens or health mutual funds. The market of real estate could emerge; in the USA some actors are already starting to invest in this field. Other potential markets are sports, events, tourism, etc. Indeed, the ECMWF expects more and more private actors to be interested in their services and they are expecting a diversification of the geographic provenance of the users.

In addition, there is an increasing need for air quality monitoring tools in developing countries and in particular in India and in China. **Most of the VAS companies interviewed were anticipating a significant increase of their extra-European sales of Copernicus-based products** in the coming years and already had carried out operational projects in such countries. However, there may be still some cultural barriers to go through as they also reported some failed attempts of the use of Copernicus, often due to management and coordination issues. In the future, such countries will probably develop their own competing regional system. Indeed, a working group in China is currently analysing the structure of CAMS to see how they could develop their own similar model with a higher accuracy over China, mainly based on the numerous existing publications on CAMS, which account for about 20% of their sources of information

As the techniques are evolving, future satellites within Copernicus may provide reliable solutions for inverse modelling, which would help identify the main polluters by tracing back the pollution fluxes to the source. Expanding the missions of Copernicus could also be the right tool for the Commission to develop a global monitoring system for carbon dioxide and methane, and for contributing to a European system to measure GHG emissions.

Economic	• Copernicus makes the different players **save time** while they process the data as it enables them to **identify hotspots** where to get more accurate data • Copernicus has a rather **strong network effect** • The small and micro companies operating in the air quality sector interviewed for this study consider that **between 3% and 10% of their revenues** can be attributable to Copernicus • Copernicus has **improved the quality of the forecasts at the scale of city by up to 20%** • *Copernicus can help take the* ***opportunities to make revenues on some niche markets*** *(tourism, real estate agencies, etc.) (expected)* • *Copernicus can help take the opportunities to* ***make revenues with local authorities in non-Western countries*** *where the topic of air quality is not yet covered by the public sector (expected)*
Social	• CAMS improves the accuracy of the air quality forecasts and thus contributes to **reducing the air quality risk for the health of the citizens** and the related costs

Environmental	• Better monitoring air quality **help reduce the negative impacts on ecosystems, animals and infrastructures** which also have a cost for the local authorities • Copernicus is a **key tool for research on air quality and on climate change**
Strategic	• As Copernicus provides a harmonised data all over the globe, it facilitates the **coordination at the international, European, national and local levels to implement the right policies to fight against air pollution** • Copernicus helps **monitoring the air quality over areas which did not have any tools to do so** and enables to control the data provided by the countries on a declaratory basis for **more transparency** • *Copernicus could help in the future to **trace back the polluters** thanks to inverse modelling (expected)*

Figure 128 - Synthesis of Copernicus impacts on Air quality management (Source: PwC-Strategy& analysis)

Voice of Copernicus' users: SWOT[375]

STRENGHTS

- Copernicus continuity improves operational applications such as urban air quality monitoring.
- Copernicus provides a reliable good quality data, notably data on pollen and UV with a quality which has no equivalent.

OPPORTUNITIES

- There is demand for systems to trace back pollutant fluxes over the globe (today it is already possible with CAMS but quite complicated and not precise enough to have a legal enforcement).
- For the moment, local authorities have no legal obligation to monitor air quality at their scale, but it may change in the future, expanding the market for VAS companies.
- There is an increasing need for air quality monitoring tools in developing countries and in particular in India and in China.
- Numerous new actors may want to buy air quality forecasts, such as insurance companies, actors of the health sector, events organisers, etc.
- The models are constantly being improved, maximising the potential benefits of Copernicus.
- New niche markets should emerge (e.g. tourism, real estate, etc.).

WEAKNESSES

- The access to the CAMS catalogue is complicated.
- For very local applications, at the scale of a fabric for example, Copernicus has a limited impact.

THREATS

- The development of individual sensors and other kinds of very customised tools could compete with CAMS near-real time air quality analysis.
- Some regional competitive initiatives may be under development for strategic markets (China, India, etc.)
- In France, the AASQA are internalising more and more activities threatening the existence of private actors on this sector on the French market.
- The development of sensors on connected objects could limit the use of Copernicus data.

[375] *PwC-STRATEGY& analysis, on the basis of interviews conducted in 2016 (cf detailed list of interviewees in the appendices)*

Policy recommendations to foster Air quality through Copernicus

Strategic pillar	Sectoral recommendations for policy action	Priority level
Pillar I: Ensure access to data	***#AQ-1 – Keep improving the access to CAMS products*** The data should be made as available as possible for all kinds of users. Indeed, it can be fastidious for users to understand the catalogue of data and to download the right data.	3
Pillar II: Support innovation	***#AQ-2 – Involve the research community in the development of CAMS*** The scientific research is fundamental for the development of CAMS in order to produce performant products, adapted to the market.	1
Pillar II: Support innovation	***#AQ-3 - Invest on the development of inverse modelling services*** Inverse modelling is not fully operational with the current available Copernicus products. Many public and private actors need inverse modelling for developing new applications.	2
Pillar II: Support innovation	***#AQ-4 – Include satellite data in national reportings*** National reportings should include satellite data for more comparability of the results and more transparency.	2
Pillar III: Increase awareness	***#AQ-5 - Increase awareness on Copernicus in developing countries*** Developing countries and in particular Asia are a promising markets for air quality applications because contrarily to Western countries, there are less institutions taking in charge the analysis of air quality, leaving more room for the private sector. However, in Asia, CAMS is not very famous, (the awareness rate of Copernicus in Asia is estimated by one of the interviewees at 2%), the "National oceanic and Atmospheric Administration" (NOAA) for example is more famous. It would thus be interesting to design specific campaigns over the most promising areas.	1
Pillar III: Increase awareness	***#AQ-6 - Advertise CAMS to SMEs and provide training*** Today, most of the initiatives to increase awareness of CAMS and support SMEs are in France, and even in France the communication channels are too specialised to reach a non-expert audience. It would be interesting to communicate on CAMS through more main-stream channels of communication for SMEs and providing training on how to use CAMS products.	2
Pillar III: Increase awareness	***#AQ-7 - Advertise CAMS to the international organisations and public authorities*** Today, the main barrier to a market uptake in the field of air quality is not that CAMS is delivering free data, because it is possible to refine this data and sell it, it is that there are almost no citizen in the world willing to pay for Copernicus data, only few institutions are willing to pay for in-depth study of the Copernicus data. However, international organisations and public authorities should be the ones buying air quality for the citizens. The European Commission could have a role to play to demonstrate to these actors why they should use CAMS.	2
Pillar III: Increase awareness	***#AQ-8 - Advertise the national tenders at the European scale*** There is a lack of bidders on public tenders in the field of air quality, there are too few actors having the right capabilities to answer so it may be useful to advertise the national tenders at the European level to increase the number of potential bidders.	3
Other:	***#AQ-9 - Impulse a higher level of air quality control at the European level through policies*** Impulsing a higher level of air quality control at the European level could be done by implementing a polluter-payer principle and incentivising governments to monitor industrials emissions at their level. In Singapore, it is already the government who monitors industrial emissions.	1
Other:	***#AQ-10 - Better coordinate the climate and air quality policies*** Although climate and air quality are traditionally considered as different policy areas, an integrated or coordinated policy approach may lead to significant benefits and avoid trade-offs.	2

Part (e) – Overall assessment of the Copernicus downstream sector and end users

Comparative analysis of Copernicus value chains

The benefits of Copernicus on the EO downstream and end user markets were assessed on 8 selected value chains: Agriculture, Forestry, Urban Monitoring, Insurance, Ocean Monitoring, Oil & gas, Renewable Energies and Air Quality. Over the 2015-2020 period, Copernicus economic value is estimated **between EUR 480 million and EUR 3,135 million for the EO downstream and end user markets**. The enabled revenues for the intermediate users represent between EUR 365 million and EUR 798 million while the end users benefits represent between EUR 119 million and up EUR 2337 million. In terms of employment, Copernicus is forecasted to support a cumulated total **between 3,050 and 12,450 jobs years over 2015-2020**.

Sectoral overview of intermediate users' benefits

The Copernicus benefits vary between the value chains, depending on the weight of the domain on the EO downstream market and the penetration rate of Copernicus. Though some value chains are expected to experience very high growths in the coming years (particularly Agriculture, Insurance and Ocean Monitoring), all the sectors considered are forecasted to witness a positive evolution of Copernicus economic impacts.

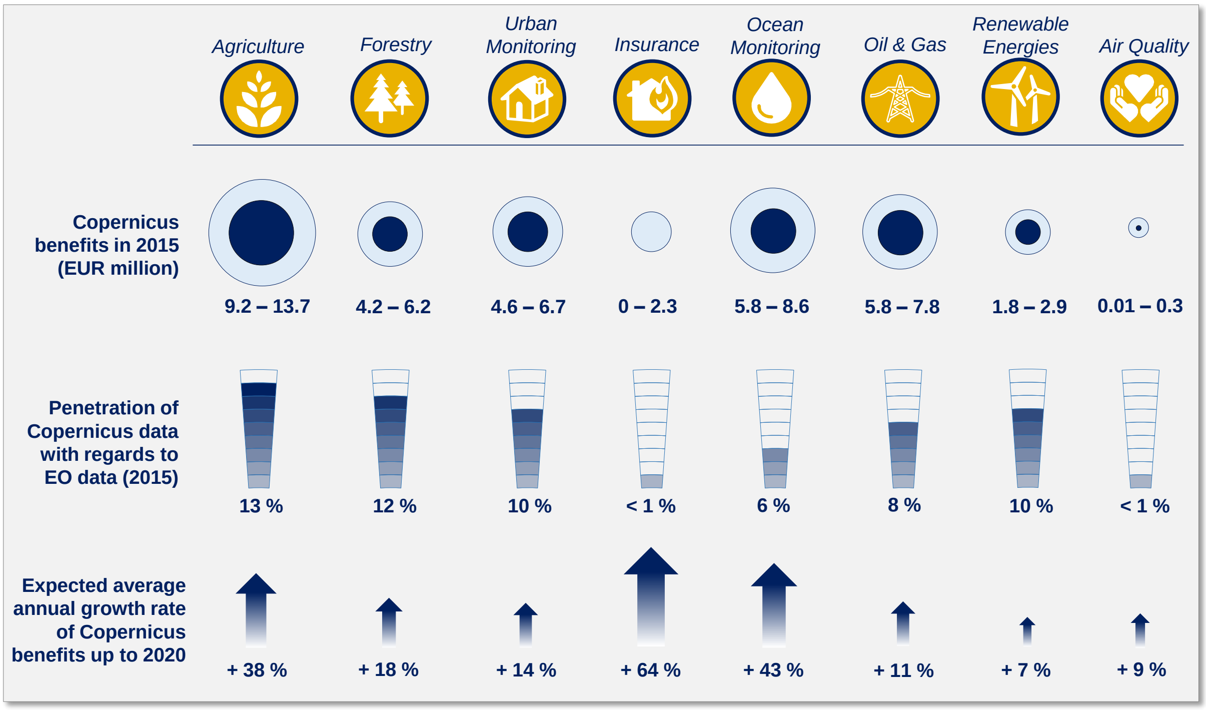

Figure 129 - Sectoral overview of intermediate users' benefits (Source: PwC-Strategy& analysis)

Sectoral overview of end user benefits

End users represent potentially much larger markets than the EO / GIS downstream markets, hence with potentially substantial benefits from Copernicus, for instance for Oil & Gas companies, (re)insurers or agricultural cooperatives. They generally have very specific needs, but demonstrate high willingness to pay to access tailored EO-based products with real added value for their business.

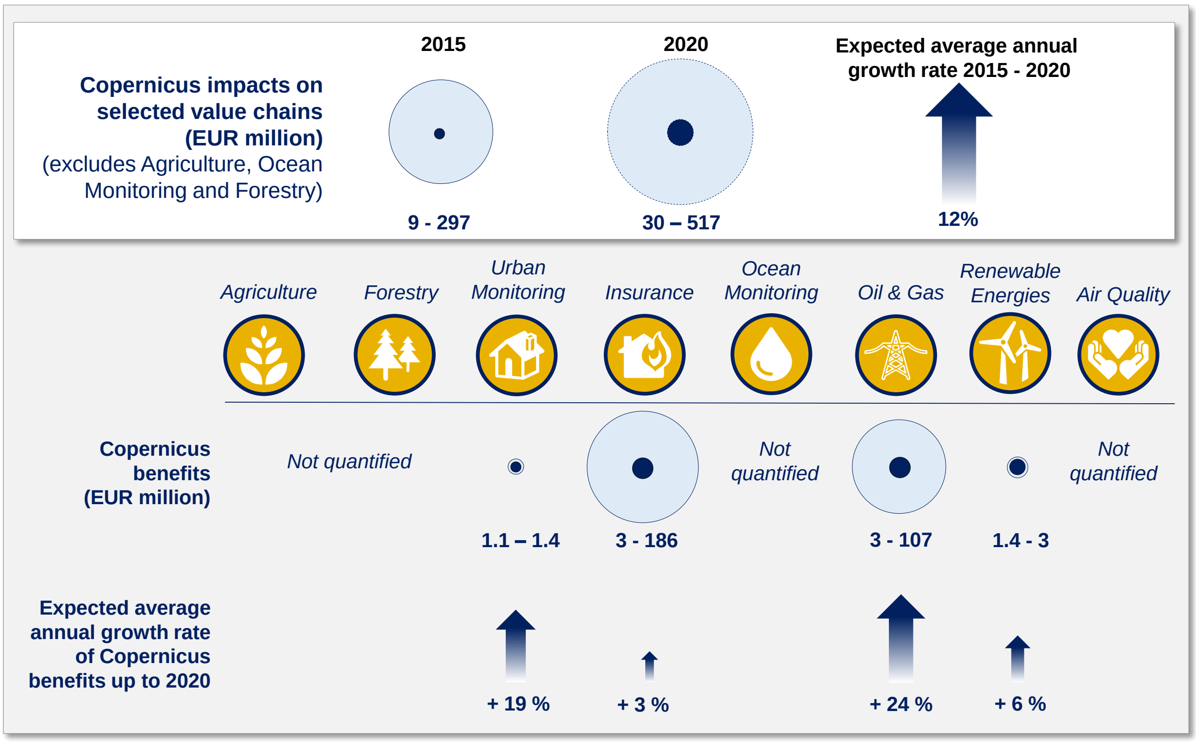

Figure 130 - Sectoral overview of end users benefits (Source: PwC-Strategy& analysis)

Analysis of the competitiveness positioning of Copernicus

Voice of Copernicus users

A survey[376] was conducted by the European Commission to collect the opinion of EO companies on barriers to the exploitation of Copernicus data and to ask them which initiatives would facilitate companies' development best. This consultation was led in the first semester of 2016, during which time 104 responses were submitted.

- Almost 2/3 of companies surveyed had been using EO data for more than 5 years
- Over 60% of the sample was composed of Small and Micro companies
- Companies surveyed were primarily active in Land Use / Cover & Change (66%), Agriculture (52%), Forest (42%), Urban Areas (38%) and Flood (36%).
- All parts of EO value chain are represented, with a majority of companies however indicating being involved in Downstream Value Added Services / GIS Services
- All parts of EO value chain are represented, with a majority of companies however indicating being involved in Downstream Value Added Services / GIS Services
- Almost 80% of respondents are based in Europe, with a high representation of German (20%) and French companies (10%)

The present section analyses the results of this consultation.

Difficulties regarding access, download and predictability of the availability of the Copernicus data

Technical aspects listed as more problematic by respondents relate to the **access to Copernicus Data** (**44%** of respondents rating having real or serious difficulty on this aspect), **storage of downloaded data (42%)** and **long-term predictability of the availability of the data (41%).**

On the other hand, respondents found the combination with other geospatial sets (54%), the processing of Copernicus data and services' information (52%) and the clarity of the metadata (46%) to be working effectively.

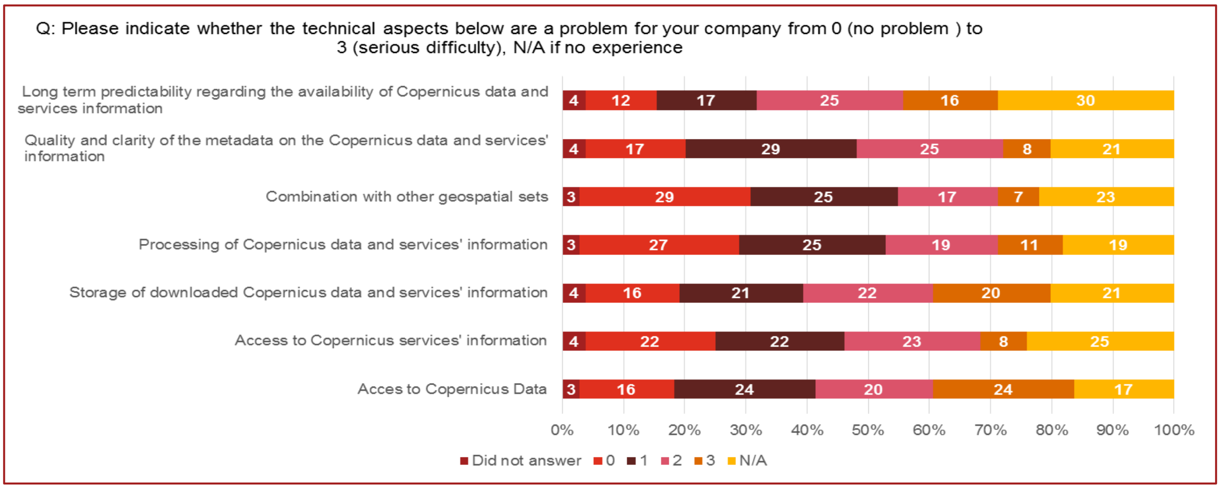

Figure 131 - Technical difficulties pointed out by Copernicus users (Source: results from EC survey http://copernicus.eu/copernicus-for-EO-companies)

Regarding **access,** priority, according to more than half of the respondents[377] should be given to establishing a **single portal** for all Copernicus products and data **(58% of respondents)** and **increasing the download speed of the portal (53%).**

[376] *http://copernicus.eu/copernicus-for-EO-companies*
[377] *Percentages are expressed on the number of respondents to this question (99 companies).*

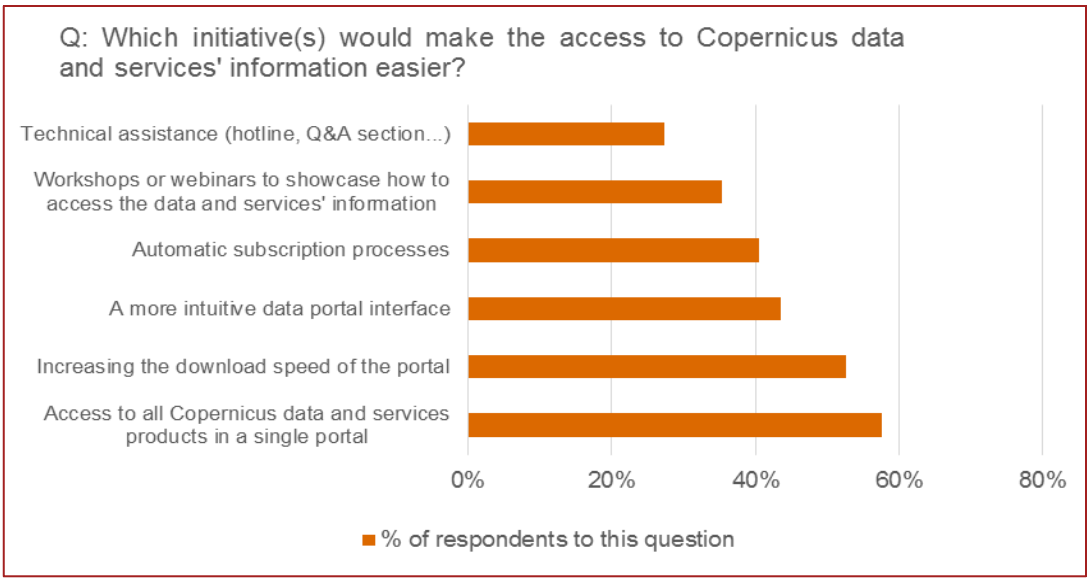

Figure 132 - Initiatives that would ease access to Copernicus data and services' information (Source: results from EC survey http://copernicus.eu/copernicus-for-EO-companies)

Regarding processing, more than half of the respondents[378] favour the development of open source conversion tools and protocols (59% of respondents), access to adequate / hosted processing solutions (55%) and standardization measures for interoperability (54%).

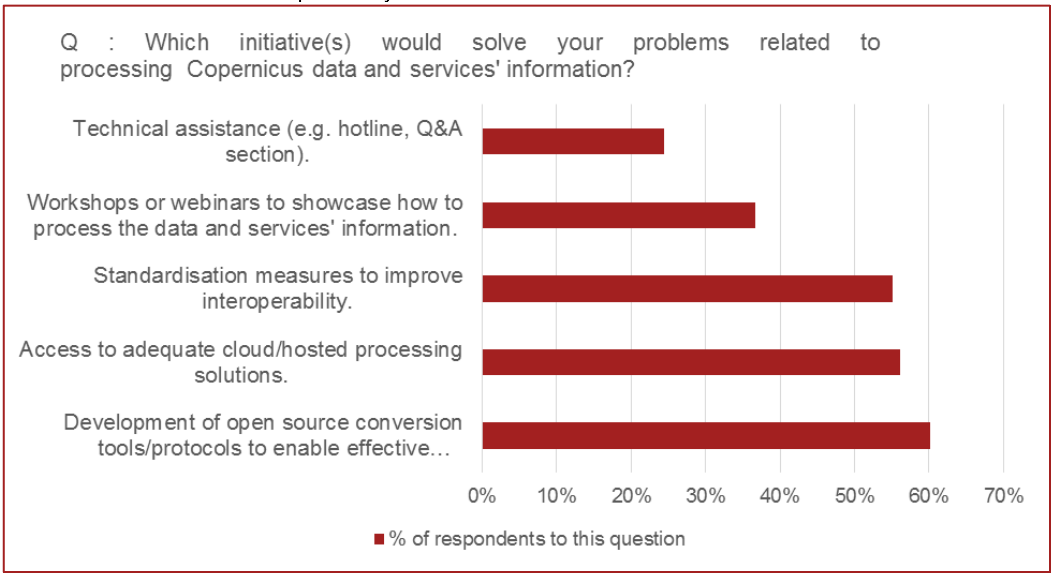

Figure 133 - Initiatives that would solve Copernicus data and services' information processing issues (Source: results from EC survey http://copernicus.eu/copernicus-for-EO-companies)

Difficulties linked to market characteristics

A large majority of respondents indicated that **both the public and private sector** (**respectively 62% and 55%)** were **problematically not aware of the benefits of EO products**, this aspect being the primary concern expressed by the respondents.

Then, more than half of companies surveyed (51%) complained about the competition from public or semi-public organisations.

On the other hand, staffing or price did not appear to be primary concerns for companies surveyed, as it did not represent a problem for respectively 50% and 48% of respondents.

[378] *Percentages are expressed on the number of respondents to this question (98 companies).*

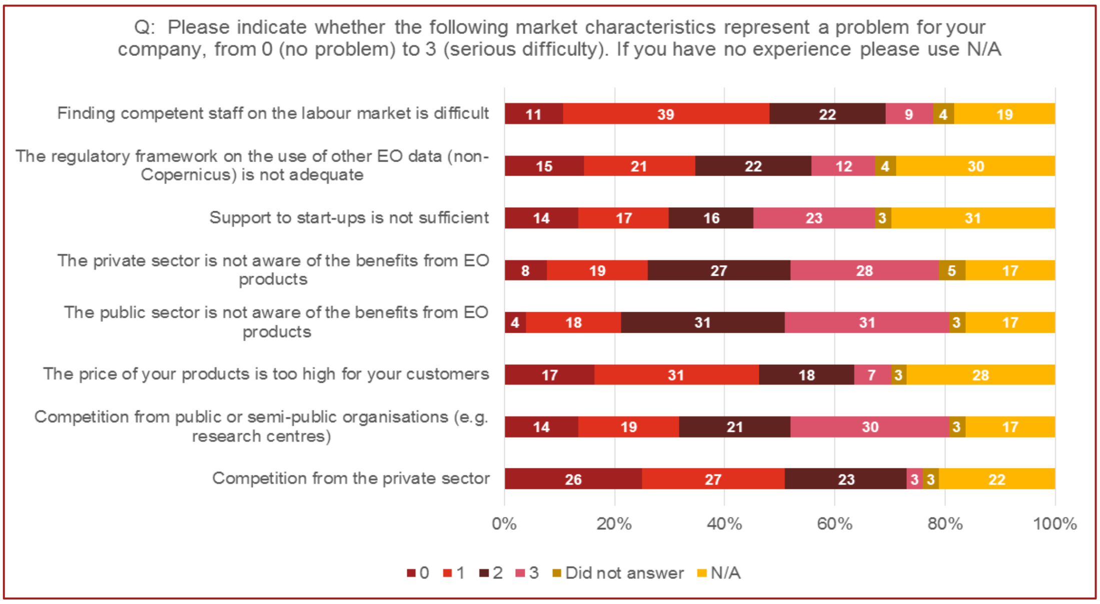

Figure 134 - Market characteristics identified as problems (Source: results from EC survey http://copernicus.eu/copernicus-for-EO-companies)

Regarding the development of the demand, respondents[379] massively recommended increasing financial support for pilot projects (67%), boosting the promotion of EO data benefits (57%) and adapting the regulatory framework to foster EO products (51%)

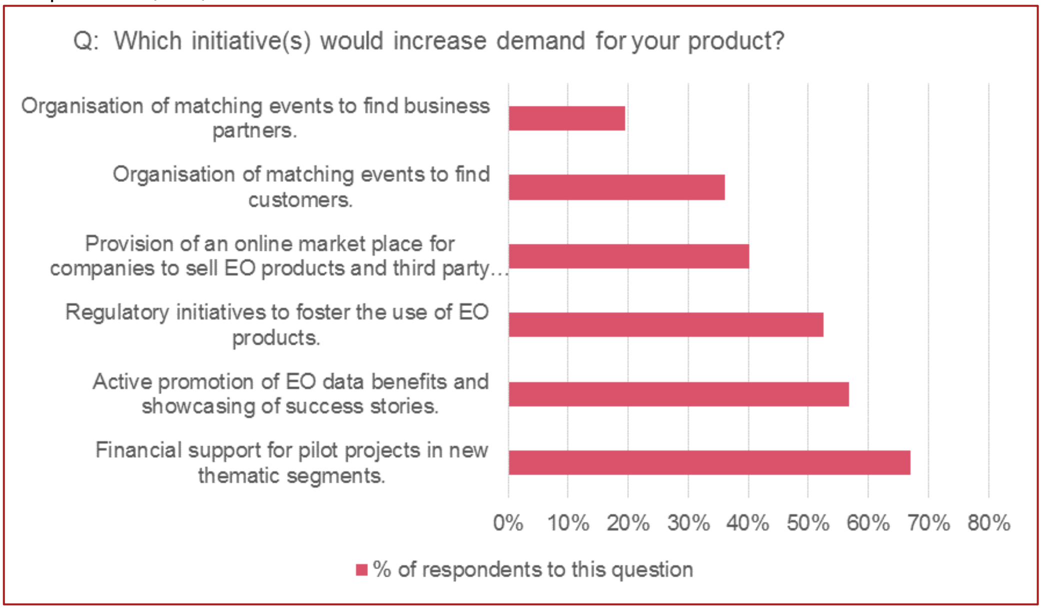

Figure 135 - Initiatives that would increase product demand (Source: results from EC survey http://copernicus.eu/copernicus-for-EO-companies)

Regarding support to innovation, respondents[380] asked primarily for strengthening the long-term predictability and availability of the data (61%), clearer boundaries between Copernicus services and the private sector (54%) and improved access to finance (42%)

[379] *Percentages are expressed on the number of respondents to this question (97 companies).*
[380] *Percentages are expressed on the number of respondents to this question (99 companies).*

Figure 136 - Initiatives that would support innovation (Source: results from EC survey http://copernicus.eu/copernicus-for-EO-companies))

Initiatives to foster international development

Regarding past initiatives, respondents[381] found matching events in the target country, with both customers and partners (47%) and the establishment of EU financial instruments for pilot projects abroad (40%) to be most effective.

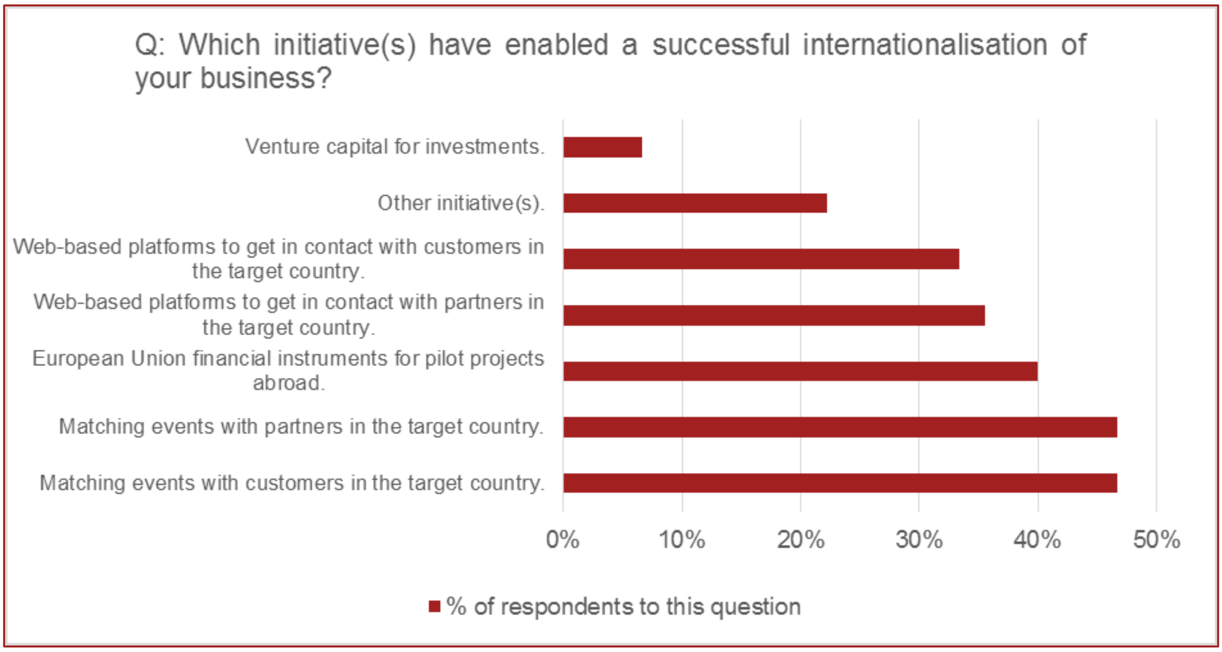

Figure 137 - Initiatives that would enable a successful business internationalization (Source: results from EC survey http://copernicus.eu/copernicus-for-EO-companies)

When asked about best initiatives to foster future international development, respondents[382] primarily listed the creation of EU financial instruments for pilot projects abroad (76%).

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[381] *Percentages are expressed on the number of respondents to this question (45 companies).*
[382] *Percentages are expressed on the number of respondents to this question (21 companies).*

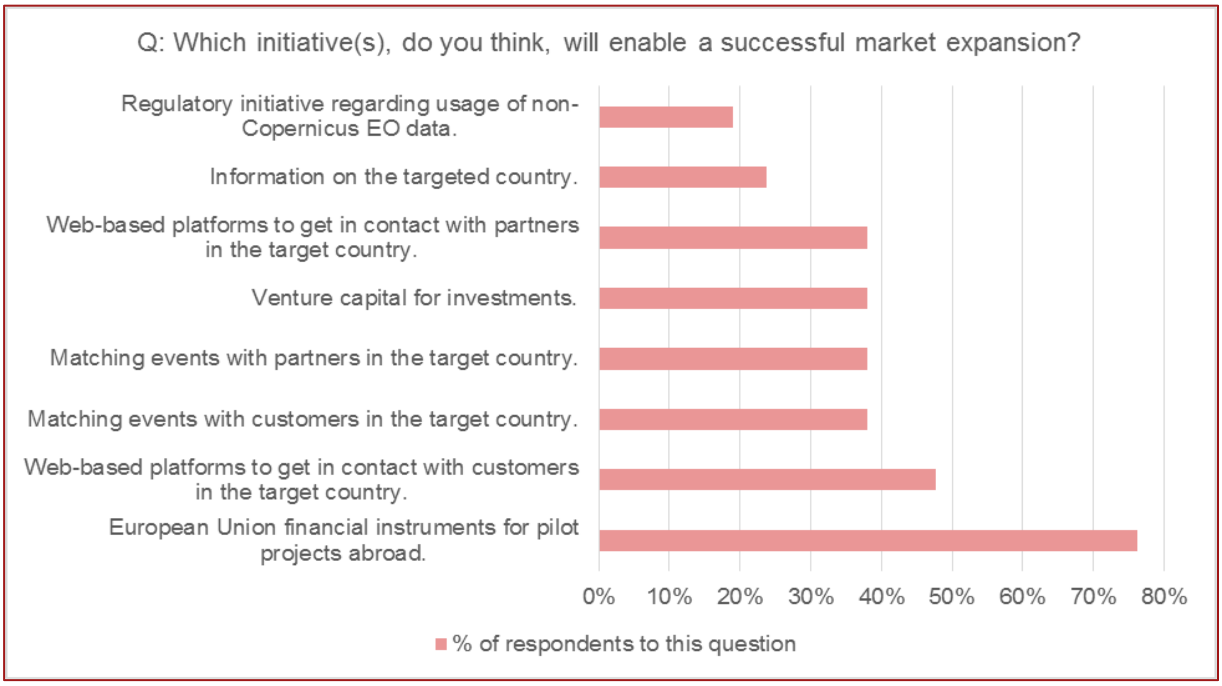

Figure 138 - Initiatives that would enable a successful market expansion (Source: results from EC survey http://copernicus.eu/copernicus-for-EO-companies)

Overall Copernicus SWOT

Based on this survey and on the large stakeholder consultation performed through this study[383], we have summarised in this paragraph Copernicus' main current competitive advantages and limits, as well as opportunities and threats that could leverage or harm the programme in the coming years. The following figure gives an overview of main points highlighted by Copernicus users. Each topic is then developed more in detail to carefully retrace users' statements.

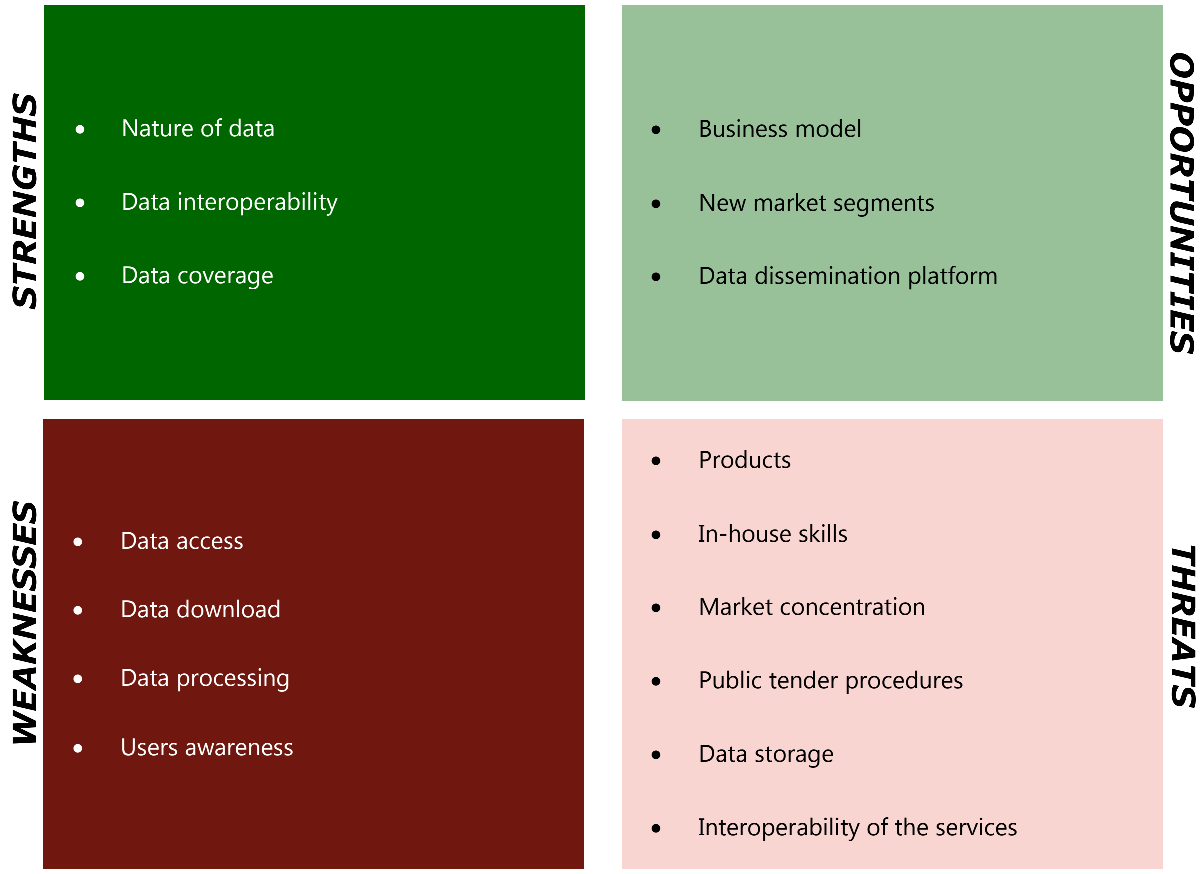

Figure 139 - Synthesis of Copernicus main Strengths-Weaknesses-Opportunities-Threats (SWOT) (Source: expert consultation; PwC-STRATEGY& analysis)

Copernicus' main strengths

- **Nature of data:** Sentinels technical capacities are Copernicus programme's main strength. The continuity, availability, accuracy, reliability of the Sentinels data, compared to competing programmes, provides a tangible added value (for example in terms of coverage, or by providing specific images that other programmes could not provide). The 5-day revisit time is a secure way to obtain identical and synthetic data.

- **Data interoperability:** Sentinels data is compatible with other data sources. Sentinels data is not competing but completing them. The resolution of Sentinels images enables to upscale detailed studies or can be a useful entry point then completed with other space data. This combination options lead to many developments, especially when the in-situ data demand is booming.

- **Data coverage:** Copernicus data are covering the whole world. This represents a lever for companies working on a global scale and expanding. Having a standard data covering the whole planet enables to have off-the-shelf products and to export them more easily. Private stakeholders are totally taking advantage of it.

[383] *Based on stakeholders consultation performed by PwC-STRATEGY&, please refer to the detailed list of interviewees in the Appendices*

Copernicus' main weaknesses

- **Data access:** Accessing Sentinels data is not considered as intuitive unless stakeholders are familiar with the EO eco-system. Moreover, except for ESA's thematic exploitation platforms (TEPs), platforms rarely focus on the user's needs and specificities. When people are looking for a rapid access to the data, the interface they are facing is judged as too complicated and not user-friendly enough. In the end, the risk is that American initiatives dealing with space data (e.g. Google Earth, Amazon S3) take this issue over and become European users' preferred access point.

- **Data download:** Downloading Sentinels data is a major issue for the Copernicus stakeholders. First, the administrative application is judged as too complex and detailed, especially compared to the Landsat one. Some users have the feeling to be traced. Another issue is the downloaded matter. It appears that stakeholders cannot download just a few images. They have to take the whole data set, which is often very heavy. In the end, it often means very long downloading time, notably in Africa, where IT infrastructures are less powerful.

- **Data processing:** Even if the data is freely provided, it still has to be refined. The large volume of data and its complexity implies huge computation capabilities which are judged as expensive and time consuming. This issue is a real obstacle to the expansion of the Copernicus programme.

- **Users awareness:** Currently, EO applications are a niche market. Current users consider that there is a real need to raise awareness among the potential users, who do not see the added value of applications based on Copernicus data. This lack of awareness constitutes a real barrier to the market uptake but also to the expanding of end users. Beyond the end user issue, intermediate users are not always aware of the potential of the Copernicus programme. There is a difference between being aware of the existence of the programme and knowing what to do with the Copernicus data, which suffers from its reputation of being too technical. Potential intermediate users are thus sometimes reluctant to jump in.

Copernicus' main opportunities

- **Business model:** Copernicus' Open Data policy is a lever for innovation as free data access enables to present proofs of concept for new applications. If a new application developed by a start-up holds the attention, the start-up's business plan is viable thanks to the free data supply. Even if the Open Data policy does not always lead to bigger margins, it enables tangible costs savings and thus constitutes a vector for innovation and growth.

- **New market segments:** Intermediate users are quite optimistic about the potential growth of the market. There are huge opportunities to address new end users' needs, especially public authorities' needs and the developing countries' issues. As well, new sectors could benefit from EO, and thus from Copernicus data (e.g. tourism, gaming and culture could be contemplated). Some other applications areas are not even considered yet.

- **Data dissemination platforms:** As previously stated, various platforms are currently available to access EO data (various national initiatives, six ESA TEPs, etc.); the supply is thus quite diverse. By capitalising on existing infrastructures, Copernicus data dissemination could be leveraged. Moreover, by targeting the platforms towards specific communities, virtual research environment would emerge (as the Amazon-S3 one).

Copernicus' main threats

- **Products:** End users interviewed in the frame of this study underlined a gap between their needs and the products and services currently offered by intermediate users. They regret that the services offered do not go deeply enough in the job specifications. Today, the VAS supply is not necessarily demand driven. This issue is an obstacle to the take-off of the Copernicus market.

- **In-house skills:** Copernicus data is currently mainly used by the scientific community (especially in sectors such as Forestry, Ocean monitoring, Air quality management, etc.). Potential users are reluctant to use space solutions, as it requires expensive and time-consuming trainings for non EO-experts. This issue is even truer in Africa. Despite capacity building campaigns, large turnover among user entities jeopardises the use of EO data by non EO-experts.

- **Market concentration:** Start-ups and SMEs pointed out that the EO market suffers from a lack of private initiatives. As previously mentioned, the EO market has a strong entry barrier which is the capacity to understand, compute and use EO data. This issue seldom concerns large firms which are considerably influencing the market, as they have the power to acquire the disruptive start-ups. This 'oligopolistic trend' constitutes a threat for the diversification of the market.

- **Public tender procedures:** Copernicus intermediate users, especially SMEs, expressed the fact that the applications for H2020 calls are too time-consuming. The grading system also seems quite misunderstood. In the end, there is a risk that it might curb innovation rather than speeding it up.

- **Data storage:** The volume of data produced by the Sentinels represents several petabytes per year; it is even more considerable when these images are refined. The need in storage capacities is booming, but there are just a few stakeholders which have the capacity to store such amounts of data. In the medium term, the risk is that only a small number of data providers will offer archived Sentinels data, which will unbalance the market and go against the Open Data policy. The availability of the Copernicus data is thus threatened by a dependence phenomenon.

- **Interoperability of the services:** Currently the different Copernicus services are too much working in silos and not enough in a cross-services design. It is a barrier to a full efficiency for these services.

General recommendations

Nota bene: To identify these recommendations, the following methodology has been applied. In the frame of the series of interviews conducted by PwC-STRATEGY& with 80 users from 54 different entities, all comments expressed by interviewed stakeholders about the challenges, issues and opportunities of the Copernicus programme were listed. These remarks were then classified by thematic. For each category of user, only the most representative ones are displayed here, and ranked by priority level depending on their representativeness.

Legend:

Low impact	Low priority level
Medium impact	Medium priority level
High impact	Strong priority level

- *Recurrence among users*: Priority level derived from the representativeness of Copernicus users' voice
- *Feasibility*: Ability to implement the recommendation
- *Financial Affordability*: Ability to be inexpensive
- *Quickness*: Ability to promptly implement the recommendation
- *Strategic impact*: Ability to contribute to the European space market uptake
- *Overall priority level*: Average level of priority according to PwC – Strategy& analysis

Main recommendations expressed by public intermediate users (sample=24)

	Stakeholders review		PwC – Strategy& Analysis					
Strategic pillar	***Transverse recommendations for policy action***	***Recurrence among users***	***Feasibility***	***Financial Affordability***	***Quickness***	***Strategic Impact***	***Overall priority level***
Pillar II: Support innovation	***#PUB-1 – Prompt innovation through hackathons and demonstrators*** Today, the "killer app" which will revolutionise the market has not been found yet. **Hackathons and demonstrators still have to be organised to lead to viable applications.**	2					1

***Pillar I*: Ensure access to data**	***#PUB-2 – Address the non EO-literate users through dedicated tutorials*** EO data is mainly used by the scientific community as it is still difficult to manipulate. **The EC should provide basic tutorials to facilitate the undertaking of EO data by non EO-experts.**	3					1
***Pillar III*: Increase awareness and use**	***#PUB-3 – Focus on local authorities*** There is a lack of awareness from the local authorities. The EO applications could have a huge impact at local scale. **It could be relevant to classify the Copernicus data by territory and to gather feedback from such potential local users. The EC could also present best practice and examples to tackle local situations.**	3					2

Main recommendations expressed by private intermediate users (sample=52)

	Stakeholders review		PwC – Strategy& Analysis				
Strategic pillar	***Transverse recommendations for policy action***	***Recurrence among users***	***Feasibility***	***Financial Affordability***	***Quickness***	***Strategic Impact***	***Overall priority level***
***Pillar II*: Support innovation**	***#PRI-1 – Build common standards*** Private intermediate users are expecting **real-time data** and **a standard of low resolution processed data** furnished by the Copernicus core services to avoid duplications of basic computing work, save time and enable easy comparisons.	1					3
***Pillar II*: Support innovation**	***#PRI-2 – Balance the open data communication*** The open data policy is key and enables to build disruptive products in viable business models but it can also threaten some commercial services. In the current digital trend, end users are now expecting applications and services for free and do not take into account the underlying added value work. **The wording of the institutional communication should take care on not creating confusion between open data and free enabled services.**	2					1
***Pillar I*: Ensure access to data**	***#PRI-3 – Simplify and harmonize the data access infrastructure*** Accessing Copernicus data is a significant issue. The multiplicity of access points does not ease the work of non-data specialists. Private intermediate users express that it is positive to have such a large choice. Hence, **the data access infrastructure should be harmonized and simplified in order to facilitate data access from end users.**	3					3
***Pillar III*: Increase awareness and use**	***#PRI-4 – Appeal potential end users*** Most end users are not aware of EO data potential. **A marketing campaign underlining the savings induced by Copernicus applications based on concrete case studies would be relevant.**	3					1
***Pillar I*: Ensure access to data**	***#PRI-5 – Propose data computation services on-line*** Due to its huge volume, the Copernicus data is complicated to process and to store, thus requiring large investments. **Providing basic on-line computation services will ease this issue.**	3					3

***Pillar II*: Support innovation**	***#PRI-6 – Create a data history*** The quality of the Copernicus data is reputed but some stakeholders do not use it because of a lack of history, which prevents from developing precise models. **Creating a data history with compatible and comparable data coming from past contributing missions would be a growth lever meanwhile the Sentinel one is being build.**	3					3

Main transverse recommendations expressed by users from micro-companies (sample= 7)

	Stakeholders review		PwC – Strategy& Analysis				
Strategic pillar	***Transverse recommendations for policy action***	***Recurrence among users***	***Feasibility***	***Financial Affordability***	***Quickness***	***Strategic Impact***	***Overall priority level***
***Pillar I*: Ensure access to data**	***#MIC-1 – Enhance the distribution of Copernicus data sets*** Micro-companies encounter significant difficulties to download Sentinel data sets compared to commercial data. **The distribution method, such as downloading specific pictures and not a whole data set, and the delivery channels might be redesigned. The creation of a standard data format could be considered.**	2					1

Main transverse recommendations expressed by users from SMEs (sample=32)

	Stakeholders review		PwC – Strategy& Analysis				
Strategic pillar	***Transverse recommendations for policy action***	***Recurrence among users***	***Feasibility***	***Financial Affordability***	***Quickness***	***Strategic Impact***	***Overall priority level***
***Pillar II*: Support innovation**	***#SME-1 – Dispel doubts related to Copernicus long-term viability*** SMEs expressed their concerns regarding the durability of the Copernicus programme, the IP rules, the scale issue, the data storage, etc. **They are expecting clear signals from the EC on a long-term and clear strategy for the Copernicus programme in order to secure their products.**	1					2
***Pillar II*: Support innovation**	***#SME-2 – Clarify and ease the administrative burden on H2020 calls*** SMEs are significantly losing time on the administrative part of the H2020 calls at the cost of the technical one. SMEs are also confused by the large topics proposed. **The EC should design more precise calls and present them as R&D levers, even if the proposals are not successful.**	3					2
***Pillar II*: Support innovation**	***#SME-3 – Convince business angels to invest in Copernicus-based products*** Some SMEs in the EO market are only viable due to subsidies and public funds. **Campaigns should be conducted to encourage business angels to jump in.**	2					1

Main transverse recommendations expressed by users from large companies (sample=13)

	Stakeholders review		PwC – Strategy& Analysis				

Strategic pillar	***Transverse recommendations for policy action***	***Recurrence among users***	***Feasibility***	***Financial Affordability***	***Quickness***	***Strategic Impact***	***Overall priority level***
<u>Pillar II</u>: Support innovation	***#LAR-1 – Coordinate innovative initiatives among European stakeholders*** Cooperation between European stakeholders on innovative initiatives should be improved to remain competitive and be able to face global IT firms. **A coordination initiative supported by the EC could be useful to share breakthroughs (online forums, lessons learned, best practices).**	2					2

<u>Main recommendations expressed by Copernicus end users (sample=14)</u>

	Stakeholders review		***PwC – Strategy& Analysis***				
Strategic pillar	***Transverse recommendations for policy action***	***Recurrence among users***	***Feasibility***	***Financial Affordability***	***Quickness***	***Strategic Impact***	***Overall priority level***
<u>Pillar I</u>: Ensure access to data	***#END-1 – Insist on the durability of the Copernicus programme*** End users are expressing a confidence issue, wondering if the Copernicus programme will last on the long-term, which is an obstacle to a real economic take-off. **The EC should communicate on the durability of the programme to reassure the market.**	1					2
<u>Pillar II</u>: Support innovation	***#END-2 – Change the EO paradigm*** End users are not interested in the origin of the information; they just consider EO data as part of a larger ensemble. **In the current Big Data context, EC should consider the EO market through the ICT prism.**	2					1
<u>Pillar III</u>: Increase awareness and use	***#END-3 – Federate new comers in the Copernicus community*** End users report a lack of understanding between their specific job issues and the EO experts. **The EC could set up workshops between the Copernicus community and potential end users. An exchange platform where end users post their needs and VAS stakeholders offer their expertise could be implemented.**	3					2
<u>Pillar I</u>: Ensure access to data	***#END-4 – Propose capacity building solutions*** End users are not EO experts and they are asking for capacity building initiatives. **The EC could propose basic EO training based on MOOCs or a FAQ with a user-friendly interface where questions could be asked.**	3					1

Conclusion

This analysis has been carried out within the assignment "Study to examine the socio-economics impacts of Copernicus in the EU". The purpose of the present report was to provide an overview of the EO downstream market and on the sectoral use of EO data, with a focus on eight downstream domains/user segments ensembles – denominated as "value chains" – under scrutiny for the study.

The present report first provided an overview of the EO downstream market, as well as of the GIS market.

For benchmark purposes, it also analysed the Landsat programme and the innovative ecosystem of EO 2.0 players that are using sources of EO data other than Copernicus.

This study then deep dived into eight promising value chains in which Copernicus programme output is currently used: Agriculture, Forestry, Urban monitoring, Insurance, Ocean monitoring, Oil & Gas, Renewables energies and Air quality management.

Copernicus barriers to market uptake were finally globally assessed, to identify transverse recommendations for policy actions to help foster the overall Copernicus market in the coming years.

Main characteristics of the EO downstream market

The European EO market is valued between EUR 2,050 million and EUR 2,410 million, divided between EO satellite operations (upstream part of the supply chain), EO data acquisition and storage (midstream part), and EO data processing to provide value added services to end users in many different sectors (downstream part).

The global EO downstream market is valued at EUR 2,751 million in 2015 with an annual growth rate of 11.31%. The European market share, estimated at EUR 632 million in 2015, is growing. The EO downstream market is following strong trends like vertical integration, Unmanned Aircraft Systems, cloud computing, etc. The main innovation in the EO downstream market is the implementation of platforms. It will drastically change the access to the data over the coming years.

EO 2.0 players are entering the markets with an innovative approach of the sector. These stakeholders, vertically integrated, have in-house capabilities to manufacture satellites but also to handle the data and propose services.

Lessons learned from the Landsat programme are fundamental to support the creation of a real space ecosystem in Europe.

Main socio-economic results of Copernicus opportunities on sectoral value chains

Agriculture

The EO downstream revenues related to Agriculture is valued at more than EUR 70 million in 2015. Sentinel-1 and -2 data is used by many public and private service providers in order to develop precision farming applications, seasonal mappings of cultivated areas, field scale and crop dynamics mapping, irrigation management and drought monitoring, and contributes to food security monitoring and agriculture development in Africa. Thanks to applications based on Sentinel data developed by VAS companies, farmers increase their productivity by a more efficient and appropriate use of agricultural inputs (up to 20%). The average share of the overall revenues of service providers directly attributable to Copernicus is of approximately 13.89% (minimal estimation) in 2015 and could reach 17% in 2020. A higher estimation, which would be calculated by including the GIS market would be of approximately EUR 13.69 million. Copernicus data in the agricultural field has led to moderate job creation, but should create additional business opportunities and enable service providers to boost their sales additionally.

According to the stakeholders' consultation, Copernicus data represents approximately 13.89% of the total EO data used by intermediate users. Thus, the total current Copernicus enabled revenues for European VAS operating in the precision farming sector is of approximately EUR 9.21 million (minimal estimation) corresponding to 2.49% of the total revenues of the European precision market sector. The contribution of Copernicus to overall enabled revenues is expected to rise in the coming 5 to 10 years – not only are most of the stakeholders planning on integrating a larger portion of Copernicus data within the overall EO data processed, but also because most applications based on Copernicus data were at an initial phase at the time of study.

Revenues emanating from the European precision farming market are expected to reach EUR 641 million in 2020 (with global revenues for the precision farming market of EUR 4.28 billion). Considering that the market share of satellite imagery in the precision farming sector increases at a regular pace, it would represent 34.6% of the market in 2020, which corresponds to EUR 221 million. In parallel, the revenues directly attributable to Copernicus should increase and reach approximately 17% of the service providers' overall revenues in 2020, corresponding to EUR 37.7 million (minimal estimation). Taking into account the fact that the European GIS market for 2015 corresponds to 2.08 times the EO market for 2015, a higher estimation would consider that the GIS revenues directly attributable to Copernicus for precision farming applications would be of around **EUR 78.24 million** in 2020.

The following chart summarises the benefits derived from the Copernicus data & products for intermediate users, on the European precision farming market, over the period 2015 – 2020.

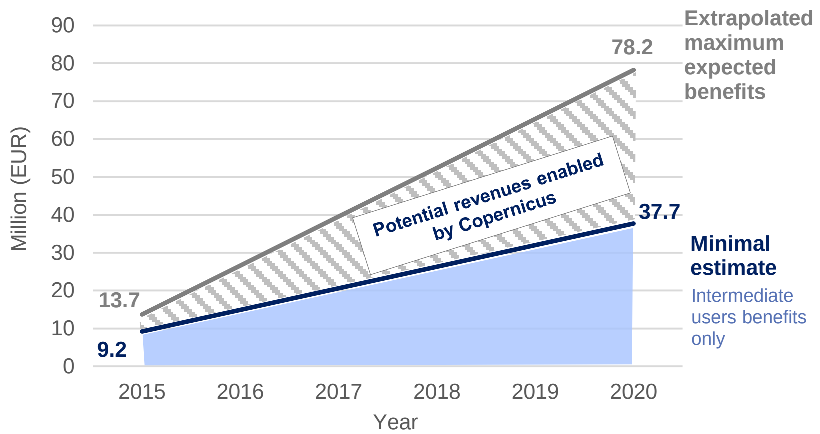

Figure 140 - Current and prospective enabled revenues by the availability of Copernicus data in Europe for precision farming (Sources: expert consultation; PwC-Strategy& analysis)

In addition to these economic impacts, precision farming applications based on Sentinel-2 data enable farmers to produce food of better quality and less detrimental for human health. Precision farming services reduce the potential negative impact of agriculture on the environment by enabling a more efficient and appropriate use of inputs.

Forestry

EO downstream revenues for forestry are valued at EUR 36 million in 2015. Forestry-related geoinformation services are currently being used mostly by public end users (approximately 90%, with the private sector constituting the remaining 10% of the user base).

90% of the stakeholders interviewed within this assessment are currently using Copernicus data in view of developing forestry-related products and applications to a certain extent - Copernicus data currently contributes to approximately 11.50% of the total amount of EO data used (minimal estimation).

In particular, Sentinel-1 and 2 data are currently already used by many of the public and private intermediate users developing forestry-related products. Sentinel-1 data, thanks to its short repeat frequency, is particularly useful to monitor vast forest regions and more specifically in order to detect illegal logging and deforestation.

The combination of Sentinel-1 and Sentinel-2 data will add value to global forest monitoring systems which provide a sufficient amount of comparable data in order for example to perform National Forest Inventories and country wide maps. Sentinel-2 data combined with SAR data is particularly suitable to measure forest biomass (in the framework of the REDD programme more specifically) and to monitor changes in forest cover (reductions due to deforestation or natural disasters for example or increase of forest areas through afforestation). Copernicus data is however not particularly useful to perform degradation assessments.

With approximately 11.5% of all EO data used being Copernicus data, a conservative estimate of the value of Copernicus data to forestry management is just under EUR 4.20 million in 2015. The impact of the Copernicus programme for forestry-related services is expected to grow in the next 5 to 10 years. Using the assumption that the average CAGR in EO imagery over 2015-2020 is 12.63%, a conservative estimate of the value of Copernicus data in 2020 is around EUR 7.60 million.

This should be treated as a very conservative estimate of the value of Copernicus data for two primary reasons. The first is the implicit assumption within these calculations that the value of Copernicus data and the value of non-Copernicus EO data is equivalent to the ratio of their data usage. However, it is likely that the value of Copernicus data is higher than the value of non-Copernicus EO data, given the additional benefits that Copernicus data provides. For example, Copernicus data offer advantages such as higher frequency visit and radar data, which, are useful within the forestry management domain. As a result, the share of EO downstream revenues is likely to be higher. A second reason why the actual contribution of Copernicus data may be higher is because at present the calculation only captures the revenue obtained by EO downstream companies (the intermediate users). The contribution of Copernicus data to the end users, of whom 90% are from public sector, may be sizeable, but it is difficult to determine an estimate of the size based on the available information and data.

A high estimation of the current enabled revenues of Copernicus would take into account the GIS market in addition to the EO market which would correspond to EUR 6.21 million in 2015 and would rise to EUR 15.81 million in 2020.

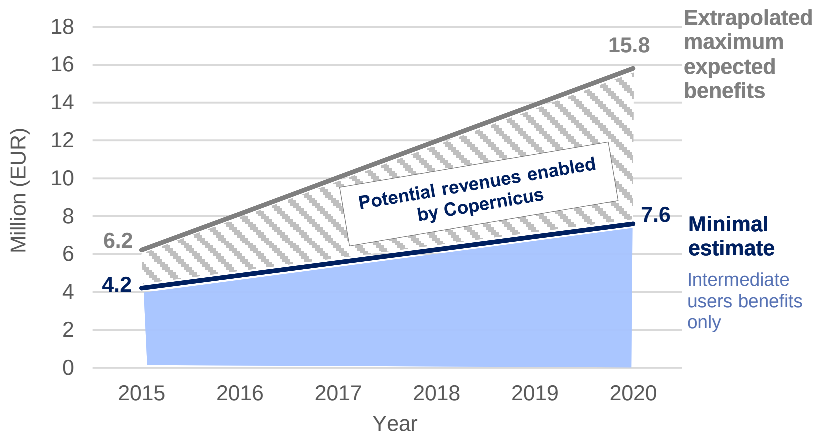

Figure 141 - Current and prospective enabled revenues by the availability of Copernicus data in Europe for Forestry (Sources: expert consultation; PwC-Strategy& analysis)

The integration of Sentinel data in forestry related projects also contributes to reducing the negative environmental impacts related to several forestry activities: by an improvement of the monitoring of deforestation and forest degradation globally for example or throughout a better prevention of forest fires. Indeed, by improving the prevention and monitoring of forest fires, the use of Sentinel data contributes to reducing the negative impacts on public health that can arise from such issues

Urban Monitoring

The market for urban management is estimated to be of EUR 45.50 million in 2015, being 5 times its estimated size of EUR 7.86 million in 2012. This considerable market growth rate can be explained by the fact that the global smart cities market is growing – it is estimated to be of USD 312 billion in 2015 and should grow by 19.40% by 2020 – but also because new smart cities EO-based applications are being developed, as for example 3D mappings.

Sentinel-1A radar data is used for change detection and 3D modelling construction by VAS companies. Sentinel-2 data on the other hand provides relevant data for urban growth monitoring thanks to its high spatial resolution optical imagery.

The Copernicus Land Monitoring Service (CLMS) provides detailed spatial information over Europe's main urban areas, thereby supporting applications such as urban planning. Some example of CLMS products are Urban Atlas and Urban indicators for municipalities.

In the near future, Sentinel-3 will deliver products such as high accuracy and-surface temperature with two-day global coverage and near-real time products delivered within 3 hours. It will provide additional information to understand and prevent Urban Heat Islands.

According to stakeholder engagements, the minimum proportion of Copernicus data to total EO data used is about 10%. Hence, a conservative estimate of the value attributable to Copernicus data within urban monitoring is EUR 4.55 million in 2015. Within the EO downstream revenues, however, this estimate is likely to be a lower-bound as Copernicus data on average is valued higher than other EO data. Hence, the actual value of Copernicus for VAS firms is likely to be higher. Assuming that the CAGR of 12.63% in EO data applies equally to Copernicus data, a conservative estimate of the expected value of Copernicus data by 2020 is almost EUR 9.87 million. By taking into account the larger GIS market rather than the EO market, Copernicus current and forecasted enabled revenues for Urban Monitoring generated by GIS data and services companies is estimated at EUR 6.69 million in 2015 up to EUR 10.44 million in 2020.

Beyond the VAS firms, there are additional elements of the urban monitoring value chain likely to benefit from Copernicus data. The impact of Copernicus data varies for each application, but ranges from high, in the case of contributing to 3D models and detection of slow landslides, to low, such as in applications in high frequency monitoring to improve accuracy and for monitoring urban sprawl. However, the scale of this additional value of Copernicus data is difficult to estimate. The services that potentially benefit from urban monitoring are vast, covering sectors such as land use and land cover, research and development, and public services. It is difficult to establish a suitable number to approximate the size of these components as a proportion of urban monitoring activities, and by extension, Copernicus data's contribution to those activities.

The benefits of Copernicus for end users are estimated on the consideration that the investment attributable to Copernicus corresponds to the enabled revenues calculated for the downstream actors. The following chart summarises the benefits derived from the Copernicus data & products on the European Urban Monitoring market, over the period 2015 – 2020.

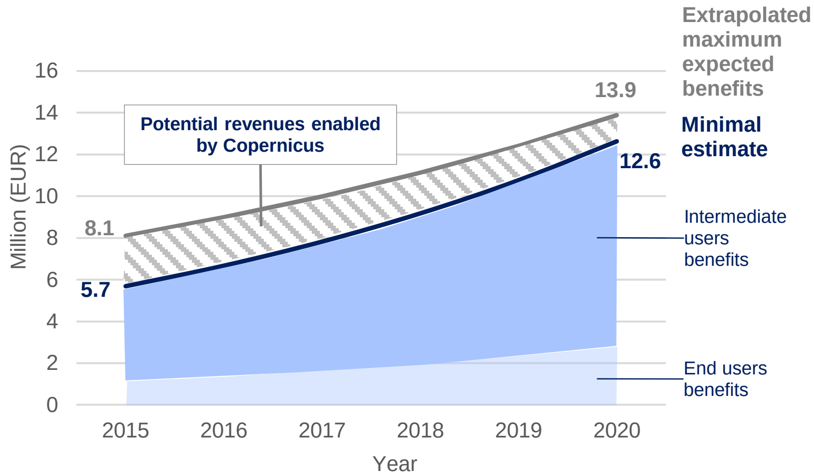

Figure 142 - Current and prospective enabled revenues by the availability of Copernicus data in Europe for Urban Monitoring (Sources: expert consultation; PwC-Strategy& analysis)

Urban products based on Copernicus provide sound social benefits. Urban Atlas ensures a VHR mapping for urban sprawl monitoring of the main European cities as well as of artificial surfaces (e.g. roads), helping to monitor the various issues linked to the phenomenon.

Copernicus urban products also have considerable benefits from an environmental standpoint. They often include low resolution biophysical variables such as land surface temperature and the relevant data to produce high-resolution maps of artificial surfaces for example, which help monitoring Urban Heat Islands (UHI), and the related negative impacts on health (heat strokes, syncope, quality of the water, etc.), local climate (e.g. increasing rainfalls), animals and plants up to 10 kilometres around the city, and increasing energy usage for air conditioning and refrigeration.

Insurance

As of 2016, the economic benefits for insurers and reinsurers which can be attributed to Copernicus remain very low, due to both its limited use as a data source and the moderate added value of EO in general over other data sources. In the coming years the use of Sentinels data should increase their economic impacts for (re)insurers.

A broad estimate can be calculated for the total potential economic impacts of Copernicus on the European insurance sector, representing between EUR 2.9 million and EUR 188 million in 2015. The lowest value includes only estimates of revenues identified through the direct discussions with different stakeholders (reinsurers and insurers). The highest estimate includes the highest extrapolation of Copernicus impact for (re)insurance market as well as the Copernicus impact for the GIS market (VAS companies and data sales). Note that in both cases, index products benefits from Copernicus did not exist in 2015.

The current impact of Copernicus on the European insurance sector remains limited for two main reasons. Some insurance applications require specific satellite capabilities which are not in the scope of Copernicus (high resolution, steerable satellites for instance), therefore with no forecasted evolution. Other applications, especially the development of index products, do not exploit Copernicus because of the young age of the constellation. However, the data required for these applications fit well with Sentinels capabilities, and the barrier will naturally fade away in the coming years. A progressive increase in the use of Copernicus can be expected on this aspect, as many insurers and reinsurers already expressed their interest in the type of data delivered by the Sentinels. However, it is important to note that the insurance parametric products developed, as a new market, weigh for few in the insurance revenues in Europe (though no consolidated figure exists, below 5% seems a realistic assumption). This market will rather grow in emerging countries where agriculture is subject to hostile natural conditions with limited financial protection. India, Ethiopia and Kenya are examples of countries where this market has recently developed.

From an economic perspective, the principle of parametric insurance is much more attractive than the traditional business model, and (re)insurers have many reasons to support its development. The current main barriers to the expansion of such products are the technical knowledge to build them and the ability to connect this knowledge to the insurers' specific needs.

The forecasts for the insured losses undergone in 2020 assume a constant increase of the 10-years average between 1980 - 2015 and 2015 – 2020. It should be noted that the strong increase between the 2015 and 2020 values is due to the low amount of natural catastrophes damages in 2015 compared to the 10-years average (around EUR 8,500 million).

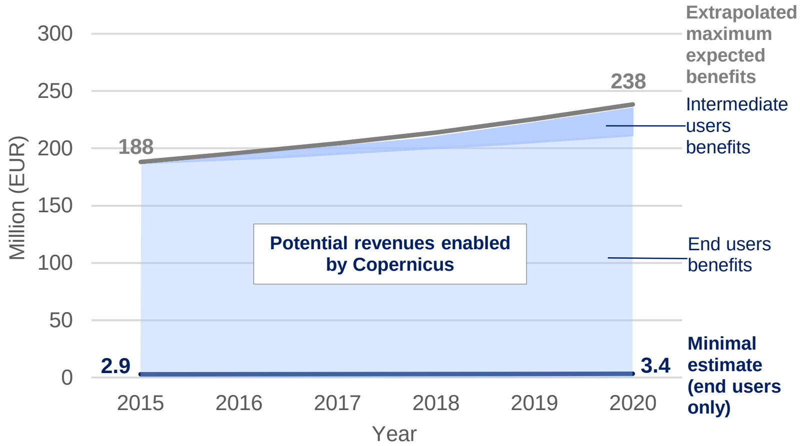

Figure 143 - Current and prospective enabled revenues by the availability of Copernicus data in Europe for the Insurance sector (Sources: expert consultation; PwC-Strategy& analysis)

The benefits of Copernicus go beyond the purely economic frame as some of its applications are related to the management of natural disasters. This represents an absolutely strategic activity for governments and civil protection entities as a mean to protect the lives of citizen. Sentinels' large swath provides a global view of events, supporting the intervention schemes of emergency teams and providing a full picture after an event. The Sentinels radar capability is also an asset for monitoring natural disasters as some of them are directly implying high cloud coverage (storms, floods and excessive rains). The delineation maps produced support the emergency services and local authorities, and in this context the Copernicus reliable and verified data is an asset. Though commercial sources are often selected for their high responsiveness, Copernicus also provides images, especially for large scale events. In Europe the Copernicus Emergency Management Service (CEMS) exploits the Sentinels and Copernicus contributing missions to provide these maps.

In the future, Copernicus should be exploited to build parametric products. The open data concept will give access, through the enabling of viable business models for insurers, to insurance products for precarious populations. Current examples of pastoralists in Kenya and Ethiopia which can insure their herds, their main and only source for living, highlight how these populations can change their fragile situation and start growing perspectives. Here the reliability of Copernicus data and its large regions coverage are also assets to answer insurance products requirements.

Ocean Monitoring

The EO downstream revenues for ocean monitoring accounted for 16.5% of the overall EO downstream market in 2012, thus amounting to EUR 129.69 million. In 2015, ocean monitoring accounted for 11% of the global EO downstream market, with related EO downstream revenues of EUR 103.85 million.

Copernicus current enabled revenues account for 5.55% of the EO downstream market for ocean monitoring, meaning EUR 5.76 million and should reach EUR 27.89 million in 2020. A higher estimation based on the GIS market evaluates the market at EUR 8.55 million in 2015, up to EUR 58.02 million in 2020.

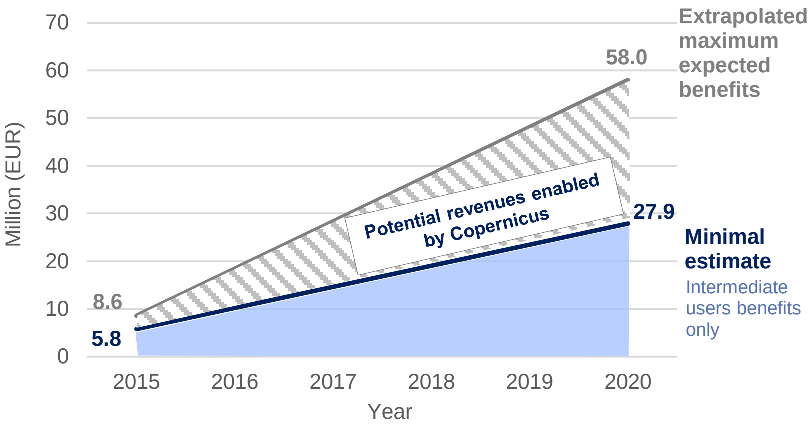

Figure 144 - Current and prospective enabled revenues by the availability of Copernicus data in Europe for Ocean Monitoring sector (Sources: expert consultation; PwC-Strategy& analysis)

One first important element to single out is that the study was performed at an early stage of the Copernicus programme, which may explain why the current enabled revenues directly attributable to Copernicus may appear to be, at this stage, quite low. Indeed, less than 20% of the stakeholders' interviewed have indicated currently using Sentinel-1 and/or 2 data. In addition, another significant element that should be singled out is the unavailability of Sentinel-3 data at the time of the study.

It should be however noted that Copernicus data has enabled service providers to decrease slightly their production costs by replacing data bought from private satellites with free Sentinels data. Indeed, the data coming from the Russian Kosmos and Canadian Radarsat satellites are very expensive – the cost of an image ranging between EUR 1,000 and EUR 5,000.

Apart from these economic impacts, services developed using Copernicus data boost sustainable fishing and limits environmental nuisance. Indeed, thanks to EO data, fish farmers better target fishing zones and thus improve their productivity and efficiency: they are able to fish a more important amount of fish in a more limited timeframe.

Oil and Gas

The current value of Copernicus data for the upstream O&G industry is estimated at least at EUR 8.75 million in 2015 (minimal estimation). The extrapolation to the overall European O&G upstream industry lead to an estimate of EUR 114.96 M in 2015. This figure, which could seem low, can be explained by the negative macro-economic context of the O&G industry due to the fall of the price of oil since June 2014. The main driver of the O&G market is the price of oil. It is also still early to properly assess the real enabled revenues since most of them face issues to

easily access Copernicus data & products. Most O&G actors interviewed are currently developing new products or improving existing ones, fully and/or partially relying on Copernicus data and/or products.
The potential value of Copernicus data for the upstream O&G industry should rise at least to EUR 32.83 million by 2020 (minimal estimation). The extrapolation to the overall European O&G upstream industry lead to an estimate of EUR 312.26 M. An important difference can be seen between 2015 and 2020 in the overall market. This strong increase in market value is mainly due to the penetration rate of Copernicus data and products which is currently very low among large integrated and oilfield services companies. However, both types of actors are very interested by such data in the future and stakeholder consultation shows interesting expected growth of revenues derived from Copernicus data and products.

The following chart summarises the overall O&G upstream benefits derived from the Copernicus data & products over the period 2015 – 2020.

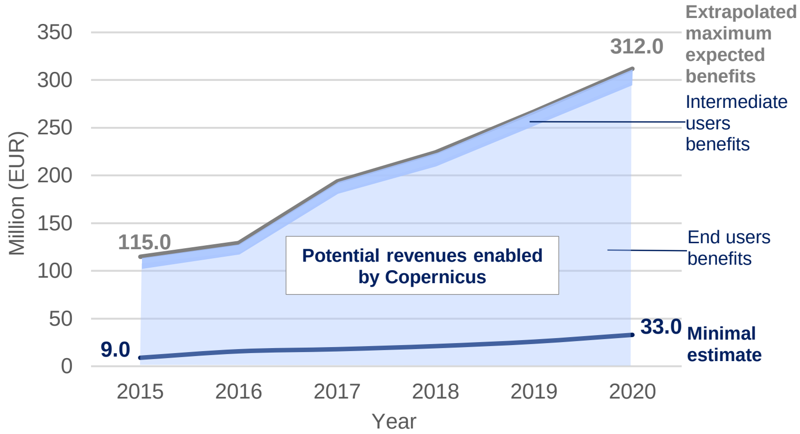

Figure 145 – Current and prospective enabled revenues by the availability of Copernicus data in Europe for the O&G upstream sector (Sources: expert consultation; PwC-Strategy& analysis)

Looking at the repartition of the potential enabled revenues, the two scenarios (the minimal estimation and the extrapolated scenario) analysed show a very large proportion of end user benefits:

- 2015: 72.69% - 88.16%
- 2020: 72% - 92.55%

Renewable energies

The European renewable energy industry is reported to have generated some EUR 130 billion turnover in the EU in 2012 and employ 8.10 million people. The biggest market in terms of revenues is trading. Today, the trading companies are almost exclusively using weather forecasts data, but some VAS companies are considering entering the market with their EO-based products.

Regarding the sales of Value Added services/products to the renewable energy supply chain Copernicus data represents a minor part of the used data source and it could be replaced. The sales of EO downstream services/products to renewable energies is estimated to be of EUR 22.73 million, and considering the sales of Copernicus data / products to the Oil & Gas industry as an upper value, it represents EUR 1.82 million in 2015 of revenues for the EO market intermediate users. A more optimistic approach can be based on the GIS market. The European market of GIS data and services for renewable energies is of EUR 33.43 million and under the assumption that the share of Copernicus data and services in the input data used by GIS actors is assumed to be the same as the share of Copernicus data and services on the EO market (8%), the Copernicus-enabled revenues for intermediate actors on the GIS market amounted to EUR 2.68 million in 2015.

In terms of **end users**, energy providers and electricity grid managers are the main end users of EO products related to renewable energies. On the public sector side, state and local decision makers also benefit from EO related products, and so do renewable energy agencies and municipalities. The end user benefits could not be quantified at this stage as there remains too much uncertainty on the actual share of their revenues that can be attributed to Copernicus itself. Considering the amounts involved, a lack of precision on this estimate could lead to substantial gaps with the actual Copernicus-enabled revenues.

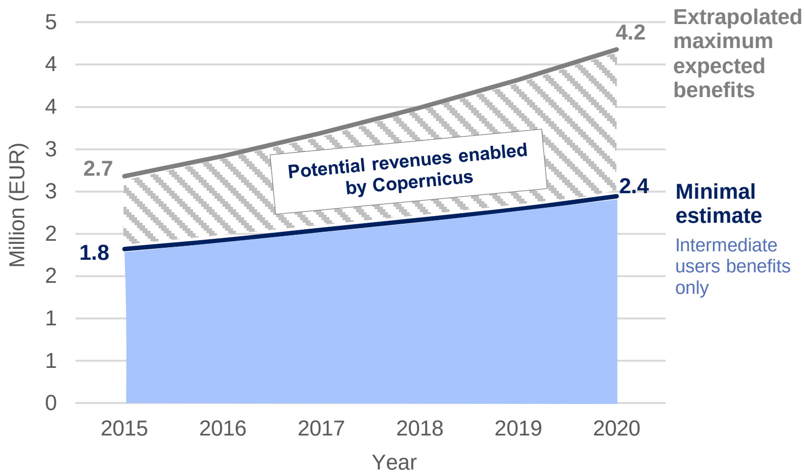

Figure 146 - Current and prospective enabled revenues by the availability of Copernicus data in Europe for the Renewable Energies sector (Sources: expert consultation; PwC-Strategy& analysis)

A few of the Copernicus core services are used to deal with renewable energies:

- Copernicus Land Monitoring Service (CLMS) provides global observation on wind characteristics, such as speed, field or stress. Corine Land cover is used for positioning wind turbines, on a site where the energy production is maximised, that is far enough from housing but close enough to the grid in order to minimise the loss of energy in transportation. Copernicus EUDEM is also used to study the relief and so the areas where there is wind. This can therefore be of interest when undertaking Energy resource assessment for selecting off-shore wind farm sites, coupled with the global wind observations provided by this Copernicus service provided by Mercator-Ocean.
- Copernicus Atmosphere Monitoring Service (CAMS) has enabled so far the development of products encompassing time-series of solar radiation reaching Earth's surface in periods of good (bright) weather, the calculation of surface solar irradiance and the monitoring of weather aleas affecting solar radiation conditions (e.g. clouds, aerosols, water vapour and ozone). CAMS provides also McClear, a free clear sky model, which is an integrated model which delivers data without clouds, available with a 24 hours delay. McClear is very useful for solar PV power production forecasts.

In terms of social impacts, renewable energies is a sector which creates jobs. For example, in 2013, the European solid biomass and biogas sectors employed 380,200 people, including many in rural areas[384]. Copernicus, by fostering the development of this market, contributes to the associated job creation.

As Copernicus helps to monitor biomass, it also helps to reduce the emissions of greenhouse gases by triggering the production of biomass. Indeed, the biomass is considered as carbon neutral as when the carbon released when solid biomass is burned will be re-absorbed during the tree growth. However, biomass combustion can have a negative impact on air quality and soil property and thus on human health and on the environment.

Air quality

The commercial market for air quality applications is rather small. The EO downstream market in the field of air quality was estimated at EUR 13.36 million in 2012 and at EUR 1.82 million in 2015. About 80% of the revenues in the air quality market come from European sales but the VAS companies consider that their main opportunities are in developing countries.

However, the overall growth rate of the market of air quality for cities and for industries has increased about 10 times over the past five years. The main business opportunities lie in specific markets (tourism, real estate agencies, etc.) for which customised in situ data is used to complete satellite data. There is also an increasing demand for air quality analysis at the scale of individuals. Research is being done on how to analyse the quality of the air breathed by a specific person based on the different activities performed within a day. Most of the actors are developing different kinds of individual sensors on connected objects which could provide in an instant customised analysis on the air quality.

[384] *European Parliament, 2015. Biomass for electricity and heating-Opportunities and challenges.Briefing.*

With the assumption that 20% of CAMS users – and so 20 % of Copernicus users in the field of air quality – are private actors and 80% are public actors, and given that the EO downstream market revenues for air quality are estimated in 2015 at EUR 1.82 million, EO revenues generated by private actors in the field of air quality in 2015 can then be estimated at EUR 360,000. The VAS companies consulted for this analysis have estimated that between 3% and 10% of their revenues associated to air quality products and services can be attributed to the enabling role of Copernicus, leading to revenues Copernicus enabled revenues for by private actors in the field of air quality estimated to range between EUR 10,900 and EUR 36,400 in 2015. For a more optimistic estimate, based on the GIS market benefits, assuming that the share of air quality in the GIS market equals the share of air quality in the EO market (i.e. 0.2%) and that the share of Copernicus in the revenues generated by air quality GIS data and products is the same as on the EO market (i.e. 10%); the Copernicus-enabled revenues in the field of Air Quality on the GIS market can be estimated to grow from EUR 0.27 million in 2015.

The end users are mainly local authorities that want to monitor the air quality on their territory and implement the right policies on traffic regulation, private companies such as waste management companies, individuals who want to be aware of the risks related to air pollution and research companies who need to better understand the climate and past greenhouse gases trends. Though they were not quantified here, benefits for end users also exist, linked to the impact of air pollution such as sick leaves, healthcare costs etc.

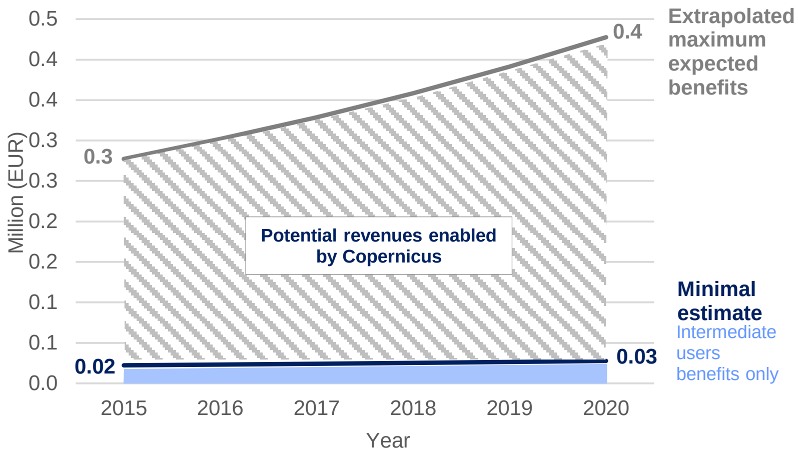

Figure 147 - Current and prospective enabled revenues by the availability of Copernicus data in Europe for Air Quality monitoring (Sources: expert consultation; PwC-Strategy& analysis)

CAMS is the Copernicus service holding the least interest in terms of business for the VAS companies. There is a number of reasons for this:

- Most of the target end users are not willing to pay for such information
- Key end users are environmental agencies and municipalities but they do not have the budget to pay for commercial products
- In most of the countries, in particular in the developed countries, the public sector traditionally covers the air quality analysis

More than the monetary impacts, CAMS has sound social and environmental impacts by improving the accuracy of the air quality forecasts and thus contributing to reducing the air quality risk. Better monitoring air quality can save millions of lives, reduce diseases such as asthma, heart and lung diseases, and help public authorities reduce spending in health or sick-leaves. It would also reduce the negative impacts on ecosystems, animals and infrastructures which also have a cost for the local authorities.

Thanks to Copernicus, it is now possible to forecast air quality all over the world, and in particular in Europe, with a common methodology. Moreover, Copernicus enables having a general qualitative appreciation of the air quality. It provides coverage (with lower resolution) in zones where there is no in situ data.

Appendix

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Table of the acronyms

Acronym	Meaning
AASQA	Associations Agréées de Surveillance de la Qualité de l'Air
Airbus DS	Airbus Defense & Space
AMA	Agrarmarkt Austria
AMIS	Agricultural Market Information System
APAC	Asia-Pacific
API	Application Programming Interface
AQI	Air Quality Indexes
ARD	Analysis Ready Data
ASIMUTH	Applied Simulations and Integrated Modelling for the Understanding of Toxic and Harmful Algal Blooms
AWS	Amazon Web Services
B2B	Business-to-Business
BDVA	Big Data Value Association
C3S	Copernicus Climate Change Service
CAGR	Computed Annual Growth Rate
CAMS	Copernicus Atmosphere Monitoring Service
CAQI	Common Air Quality Index
CFP	Common Fisheries Policies
CGI	Canadian global information technology group
CLMS	Copernicus Land Monitoring Service
CLS	Collecte Localisation Satellites
CMEMS	Copernicus Marine Service
CNES	Centre National d'Études Spatiales
CNRS	French National Centre for Scientific Research
CRW	Coral Reef Watch
CWA	Copernicus World Alliance
CWT	crop water requirements
DaaS	Data as a Service
DEM	Digital Elevation Model
DG	Digital Globe
EARSC	European Association of Remote Sensing Companies
ECMWF	European Centre for Medium-Range Weather Forecasts
EEA	European Environmental Agency
EFDC	European Forest Data Centre
EMEA	Europe and Middle-East Africa
ENVISOLAR	Environmental Information Services for Solar Energy Industries
EO	Earth Observation
EO4OG	Earth Observation for Oil & Gas
EROS	Earth Resources Observation Science
ESOC	European Space Operation Centre
ESRIN	European Space Research Institute
ET	evapotranspiration
ETM	Enhanced Thematic Mapper
FAA	Federation Aviation Association
FAO	Food and Agriculture Organisation

FAS	Foreign Agricultural Service
FISMA	Federal Information Security Management Act
FMI	Finnish Meteorological Institute
FTE	Full Time Experts
F-TEP	Forestry Thematic Exploitation Platform
GDIS	Global Drought Information System
GDP	Gross Domestic Product
GEO	Group on Earth Observations
GEOGLAM	Global agricultural geo-monitoring initiative
GFOI	Global Forest Observation Initiative
GFW	Global Forest Watch
GHG	greenhouse gases
GIS	Geo Information System
GIZ	German Development Agency
GMTED2010	Global Multi-resolution Terrain Elevation Data 2010
HAB	Harmful algla blooms
IaaS	Infrastrcture as a Service
ICT	Information and Communications Technologies
IFREMER	French Research Institute for Ocean related issues
IGN	Institut national de l'information géographique et forestière
INERIS	the Institut National de l'EnviRonnement Industriel et des RisqueS
IOGP	International association of Oil and Gas Producers
IoT	Internet of Things
IPO	Initial Public Offering
IRD	Development Research Institute
KACST	King Abdulaziz City for Science and Technology
LAI	Leaf Area Index
LEO	Low Earth Orbit
LP DAAC	Land Processes Distributed Active Archive Center
M&A	Merger and Acquisition
MDA	MacDonald, Dettwiler and Associates
MERIS	Medium Resolution Imaging Spectrometer
METOP	Meteorological Operational Satellite Program of Europe
METRIC	Mapping EvapoTranspiration at high Resolution with Internalized Calibration
MFC	Model Forecast Centres
MSS	Multi Spectral Scanner
NAIP	National Agriculture Imagery Program
NASS	National Agricultural Statistics Service
NDVI	Normalized Differential Vegetation Index
NFI	National Forest Inventories
NGO	Non-govermental organisations
NOAA	National Oceanic and Atmospheric Administration
O&G	Oil and Gas
O&M	operations and maintenance
OGEO	Oil and Gas Earth Observation group
OLI	Operational Land Imager
ONF	Organisation Nationale des Forêts

PaaS	Platform as a Service
PAC	Processing and Archiving Centre
PDGS	Payload Data Ground Segment
PEPS	Platform for the Exploitation of Sentinel products
PI	Principal Investigator
PMA	marine protected areas
PML	Plymouth Marine Laboratory
PPP	Public-Private Partnership
PV	photovoltaics
RCM	Radarsat Constellation Mission
REDD	Reducing Emissions from Deforestation and Forest Degradation
RES	Renewable Energy Sources
RMSE	root-mean-square error
SaaS	Software as a Service
SFTC	Science and Technology Facilities Council
SME	Small and Medium Enterprise
SNAP	Sentinel Application Platform
SOLEMI	Solar Energy Mining
SUD	Sentinels Users Dashboard
TAC	Thematic Assembly Centres
TEP	Thematic Exploitation Platforms
TM	Thematic Mapper
UAS	Unmanned Aircraft Systems
UAV	Unmanned aerial vehicle
UHI	Urban Heat Islands
UN	United Nations
UNECE	United Nations Economic Commission for Europe
USGS	US Geological Survey
VAS	Value-Added Services
VC	Venture Capitalist
VHR	Very High Resolution
WHO	World Health Organisation
WRI	World Resources Institute
WWW	Web Wide Web

Questionnaire

Questionnaire built by PwC-Strategy& to conduct interviews with 142 Copernicus users in 94 different entities during the first semester of 2016.

Overview of the organisation and context of the firm (Facultative)

Leading Questions	Sub Questions/explanation
History of the firm	Should be checked before interview: • Specific questions related to the particular context of the firm may be asked
Activities of the firm	Should be checked before interview: • Specific questions related to the particular context of the firm may be asked What are the more profitable areas for your firm (agriculture, oil & gas, urbanisation … etc.)?
Descriptive information on your company before starting the interview: • Number of employees • Type of company • Turnover of the company: this figure should not be asked at the beginning but during the interview	Type of companies can include: end user, VAS company, public research centre, national space agency … etc. Turnover of the company will be anonymized and used as an aggregated figure (together with all the other stakeholders)
What are your core markets? **What are your geographical core markets?**	Are you a local/national/international organisation? In which geographical area(s) are you making the biggest share of your revenues? Can you provide us with a share of revenues related to exportations outside your country? Outside Europe? What is the share of revenues coming from government/public funds?

Earth Observation in general

(Specify to interviewees that this section is on EO in general and that the following section will be focusing on Copernicus specifically)

Leading Questions	Sub Questions/explanation
When/ why/ how did your company start using EO data?	What type of EO data (sensors, resolution … etc.) are you using? Did you use other type of data before the availability of EO data (such as aerial data)? Do you use other sources of data, such as aerial, ground, maritime or even navigation data? Do you compile these types of data?
Is EO data part of your organisation's mainstream strategy?	Is the largest share of revenues derived from EO data? Are you processing your own data or do you rely on outside organisations for VAS or IP?
Have you made significant investment to be able to use EO data? (not related to Copernicus data specifically)	Have you invest in specific equipment to process or store EO data? Have you invest in specific training for your employees in order for them to be able to create value with EO data? Can you give us an idea of the size of the investment?
How do you access to EO data?	What are your main sources of EO data (Landsat, Copernicus, private-owned satellites such as Radarsat or Pleiades … etc.)? Did you encounter any specific challenges to access EO data?

What is the main EO downstream domain in which you operate (agriculture, blue economy, urban monitoring, etc.)?	How mature is the use of EO data within these downstream domains? What would you identify as main trends within these downstream domains, and how are you acting to anticipate/meet them?
If you are working in various downstream domains/sectors, can you identify any similarities in the way(s) you go to market in each of them?	Are there any significant specificities for each of the domains? What are the major differences between these sectors (eg. maturity of the market, type of users, etc.)?

Use of Copernicus data

Leading Questions	Sub Questions
When/ why/ how did your company start using Copernicus data?	What was the impact of the availability of Copernicus data, compared to regular EO data? Which Copernicus satellites are you using (Sentinels, contributing missions … etc.)?
Have you received any grants from EC or ESA related to the Copernicus programme?	Did any public contribution support the development of new products/services based on Copernicus data? Did this "money" contribute to fund R&D project, go-to-market products … etc.?
Did you make any significant investment to have access to Copernicus data?	Di you invest in specific capital (equipment, training… etc.) to have access to/use Copernicus data? What was the size of the investment required to be able to use/have access to Copernicus data?
What do you think are Copernicus' main limitations to downstream market development?	What are the barriers limiting private sector development? Do you see any way to counter these limits? If so, how?

Impact of the Copernicus data: quantitative data

(Quantify sales increase and cost reduction (revenues) per type of effect)

The following section focuses on the quantification of revenues derived from the use of Copernicus data.

The first step aims at understanding if there is any revenue (sales or cost reduction) related to products/services using Copernicus data. If so, the following questions aim at identifying the type of effect leading to sales or cost reduction (market, commercial and/or organisational effect).

So: Q1m + Q1c + Q1o = 100%

The second step aims at isolating the part of the revenue which is due to Copernicus data, through a range estimation. This exercise should be facilitated by the earlier discussion to understand the context and the importance of the use of Copernicus data.

So: 0% ≤ Q2 ≤ 100%

Main thematic	Questions
Market effect(Q1m) The availability of Copernicus data enables a better offer for the end users	Does the availability of Copernicus data have led to sales increase of existing products? Does the availability of Copernicus data have increased the sales of new products on existing markets? Does the availability of Copernicus data have led to the creation of a new market?

Commercial effect (Q1c) The availability of Copernicus data enables the development of a new or/and better commercial network for the end users	Has the participation in the Copernicus programme led to any network effects? Development of new networks and partnerships developed thanks to the Copernicus programme Development of international collaborations thanks to the Copernicus programme Has the participation in the Copernicus programme generated any reputation effects? (new contracts, new clients, etc.)
Organisational effect (Q1o) The availability of Copernicus data enables organisational improvements in the organisation	Did the programme/project lead to any organisational effects (new project management, quality control, accounting practices, etc.) • Improving production methods; • Efficiency/productivity gains.
Critical mass The availability of Copernicus data has led to the creation of new competences within the organisation and/or outside the organisation	Have there been any competence effects from the Copernicus programme (development of human capital, enhancement of the firm's knowledge base, etc.)? Have there been any training effects from the Copernicus programme (student training, internships, etc.)?
Paternity assessment	Try to quantify the contribution of Copernicus data to cost reduction and sales increase providing a range (%) (i.e. 10-15%) The lower figure should represent the minimum benefits paternity directly related to Copernicus data The highest figure should represent the maximum benefits paternity directly related to Copernicus data.

Additional questions (survey)

Leading Questions	Sub Questions
Which one(s) of the following elements lead to the most significant benefits? Multi-response possible	• Open data (free of charge or affordable access to data) • Spatial resolution • Coverage • Revisiting time • Type of sensors • In-situ data • Other: (please specify)
In your opinion, are there any barriers impeding the development of the European downstream market?	*Open question*
What types of tools/practices/regulations could be used to foster innovation on the downstream market in Europe?	*Open question*

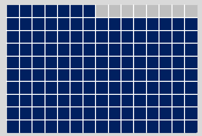
Policy recommendations

Leading Questions	Sub Questions
How do you think the EO market is going to evolve?	What do you think will be the main trends of the "future" EO market? In your point of view, what will be the main challenges of this market?
What type of support would your company/market need?	How do you assess regulations and policies currently in place? Would you implement or modify any specific policy or regulation? Do you have any specific examples of particularly supportive initiatives or policies that should be developed further? What specific initiatives could be undertaken by public authorities? What type of support do you need from local/regional/ national and international authorities?

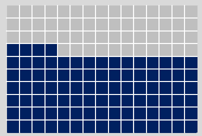
How could access to data be facilitated?	Are there any specific issues with regulations linked to access to data? What could the EC do to improve access to data?

- ➔ Would you have any specific suggestions as to whom we should interview in the framework of our study?
- ➔ Add questions linked to specific issues for each of the value chains

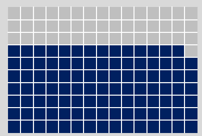
Stakeholders consultation



142
persons interviewed



94
different entities



104
participants in the Copernicus survey

INSTITUTIONAL STAKEHOLDERS

- Aerospace Valley
- Big Data Value Association (BDVA)
- Centre National d'Etudes Spatiales (CNES)
- Daithi O'Murchu Marine Research Station (DOMMRC)
- Deutsches Zentrum für Luft- und Raumfahrt (DLR)
- DTU Wind Energy
- ESA
- EU-Japan Centre for Industrial Cooperation
- Eurisy
- European Association of Remote Sensing Companies (EARSC)
- European Centre for Medium-Range Weather Forecasts (ECMWF)
- European Environment Agency (EEA)
- Finnish Meteorological Institute (FMI)
- Foundation for Research and Technology - Hellas
- French ministry of Ecology, Sustainable Development and Energy
- Global Forest Observations Initiative (GFOI)
- Global Forest Watch (GFW)
- Group on Earth Observations (GEO)
- Hespul
- Icube
- Institut Français de Recherche pour l'Exploitation de la Mer (IFREMER)
- Institut National de l'Environnement Industriel et des Risques (INERIS)
- International Space University (ISU)
- Joint Research Centre (JRC)
- Landsat program
- Marine Institute
- MESA SADC
- Netherlands Space Office (NSO)
- Office National des Forêts (ONF)
- Plymouth Marine Laboratory (PLM)
- Satellite Applications Catapult
- Umweltbundesamt
- University of Maryland
- University of the West of England - Bristol
- US Geological Survey (USGS)
- VTT Technical Re

LARGE COMPANIES

- Airbus Defence and Space
- Amazon Web Services (AWS)
- Atos
- Axa
- C-Core
- Collecte Localisation Satellites (CLS)
- CS Communication & Systèmes
- Deltares
- DigitalGlobe
- Elecnor Deimos
- ESRI
- GAF
- Google
- Groupama
- Hatfield Consultants
- Orange
- Planet Labs
- RHEA Group
- RPS Energy
- Swiss Re
- Willis Re

MICRO-COMPANIES

- AdviceGEO
- Building Radar
- Earth-i
- Gaia
- Geocento
- i-Sea
- Nazka
- Pixalytics
- Viridian Raven

SMEs

- Astrosat
- BMT ARGOSS
- Cambridge Environmental Research Consultants (CERC)
- CloudEO
- EFTAS
- Geosigweb
- GeoVille
- GIM
- Gisat
- IsardSAT
- Mercator Océan
- Nelen & Schuurmans
- Noveltis
- Numtech
- Oasis Loss Modelling Framework
- Plume Labs
- Predict Services
- Reuniwatt
- Rezatec
- Science [&] Technology
- Sinergise
- Tele-Rilevamento Europa (TRE)
- TerraNIS
- VisioTerra
- VITO
- Vizzuality

Corpus of recommendations

Landsat

Strategic pillar	Sectoral recommendation for policy action	Priority level
Pillar I: Ensure access to data	***#LAN-1 - Develop a dedicated connection for large-volume users*** The development of a dedicated connection for large volume users (both public and private) different from general throttling has largely contributed to the dissemination of Landsat data. The Copernicus programme should develop a similar access on a one-by-one basis to foster the use of Copernicus data since this type of users will download all the data anyway. In such context, the Copernicus programme should better use a collaborative approach than a conflictual one following the rules of Game Theory.	1
Pillar I: Ensure access to data	***#LAN-2 - Simplification and mutualisation of the Copernicus data access to avoid duplication at national and international level*** The Landsat programme is offering an easy and simple access to data and Landsat products worldwide for both US and international users. The Landsat access is an interesting example of architecture that enables to avoid duplication of efforts and wasted cost. The Copernicus programme should work on a simplification and mutualisation of it data access architecture. Moreover, more links with organizations such as the USGS should also be pushed forward to work on a collaborative approach, complementing and promoting what these organizations are offering to avoid duplications and wasted costs at international level.	1
Pillar II: Support innovation	***#LAN-3 - Copernicus core services should focus on the creation of public knowledge related to Copernicus products and data*** The aim of a programme such as Copernicus is to give the spark to foster the use of EO data in scientific, public and private operations of the European society. The public should be developing a fertile ground for innovation, investing to create a large public knowledge on how to process, use and analyse Copernicus data in a very specific context. Collaborations with universities and public & private administrations should enable the creation of these knowledges, contributing in the end to European economic growth.	1
Pillar III: Increase awareness	***#LAN-4 - Increase collaboration with open source and crowdsourcing communities*** Such as the USGS with Github, the Copernicus programme should push forward collaborations between Copernicus core services and crowdsourcing & open source communities. Using open innovation strategies will help raise awareness about the availability of Copernicus data for free and attract outsider from other communities, especially the coder, software and IT communities.	2
Public/Private Boundary	***#LAN-5 - Find the right equilibrium between public and private role*** Providing basic standardized information products on a routine basis plus data ready for analysis (e.g. data cubes of specific areas of interests derived from user requirements) should contribute to the dissemination of Copernicus data, especially for less technical actors. In fact, these types of product contribute to foster both the institutional and private market.	2

Agriculture

Strategic pillar	***Sectoral recommendations for policy action***	***Priority level***
Pillar I: Ensure access to data	***#AGR-1 – Facilitate access to data at a national, regional and local level in developing countries*** There is a strong need to develop and ensure understanding and access of EO data in order for the information extracted to be exploitable and useful to all users and be exploited at best. Thus, the launch of **capacity building campaigns coupled with a facilitated access to data** in developing countries could have a significant impact on driving the attention of potential users.	2
Pillar II:	***#AGR-2 – Boost synergies between service providers and potential agricultural***	

Support innovation	***end users in Africa throughout the implication of NGOs and international organisations*** In order to facilitate the outreach to potential end users in Africa, intermediate users and/or the EC should involve local NGOs and international organisations (such as the World Food Programme) in order for them to act as local relays towards end users and hence boost synergies service providers and end users in this region of the world.	1
***Pillar II*: Support innovation**	***#AGR-3 – Create specialised networks on EO products related to agriculture*** Service providers often encounter difficulties to reach potential clients. In order to boost their businesses, public authorities could envisage **creating a network of SMEs developing agricultural applications** to establish contact between the potential clients and the companies that provide the required service.	2
***Pillar III*: Increase awareness and use**	***#AGR-4 – Launch training campaigns in order to increase the awareness of end users from the agricultural sector*** **Increase awareness of end users from the agricultural** sector (especially farmers) by, for example, organising training sessions in order to showcase the potential added-value of EO data in order to increase the productivity of farmers.	1

Specific recommendations linked to food security issues in developing countries

***Pillar I*: Ensure access to data**	***#AGR-5 – Establish the appropriate infrastructure to ensure access to EO data*** **Access to data is a major challenge in developing countries – without the proper infrastructure, it will be impossible to develop sustainable EO projects. In order for EO-based agriculture products to expand in Africa, significant efforts to set up reliable infrastructure are necessary, driven by a sound political commitment from both local and international authorities to develop the appropriate capacities to support the development of these technologies.**	1
***Pillar I*: Ensure access to data**	***#AGR-6 – Increase capacity building initiatives for agricultural end users in order to ensure access, analysis and use of EO data*** Regarding projects taking place in developing countries, the Copernicus programme should set a high priority on **capacity building initiatives of agricultural end users to access, analyse and exploit data collected via EO programmes**. Indeed, know-how transfers are necessary to ensure sustainability of the programmes.	1
***Pillar II*: Support innovation**	***#AGR-7 – Envisage a regionalisation of EO products developed by VAS companies in order to respond simultaneously to identical challenges*** Regarding food security issues, many countries in Africa face similar challenges. Thus, by **regionalising their products and services for one given region, VAS companies could boost their activities in Africa and reach out to new markets**. Products could be regionalised for countries for example in which the agricultural activity is highly constrained by precipitations.	3

Forestry

Strategic pillar	***Sectoral recommendation for policy action***	***Priority level***
***Pillar I*: Ensure access to data**	***#FOR-1 - Define an adapted strategy to increase access to data*** Data access is considered as one of the main weaknesses of the Copernicus programme. Thus, the EU needs to define a specific strategy and invest in the downstream market in order to make the data available to all potential users.	1
***Pillar II*: Support innovation**	***#FOR-2 - Boost the creation of a sustainable market for EO forestry-related products*** The downstream market for forestry-related products and applications relies mostly on public funding and is thus not sufficiently sustainable. Hence, the relevant DGs of the **EC should contribute to creating a sustainable market for EO forestry-related issues** and, in this context, could develop a **coherent funding strategy of EO-related projects** (in Europe but also in Africa).	2
***Pillar III*: Increase awareness**	***#FOR-3 – Foster the promotion of the added value of EO data in forestry-related issues*** The EC should continue to encourage strongly the **launch of public campaigns throughout the world in order to showcase the added value of EO data in forestry-related issues** and ensure that an appropriate follow-up is done. This would increase the range and number of private and public end users, in the	1

	framework of the REDD programme but not only, and create further opportunities for service providers.	

Specific recommendations linked to the **REDD programme in developing countries**

Pillar I: ***Ensure access to data***	***#FOR-4 - Improve the coverage of the Sentinel-1 mission over Africa to better monitor deforestation and forest degradation*** **The added value of EO data in order to monitor deforestation and forest degradation in developing countries is considerable. In the Congo basin for example, countries are in great need of improving their existing forest monitoring systems. However, they experience a lack of relevant and precise data on their regions. Thus, if the coverage of Sentinel missions (especially Sentinel 1) over Africa were to be increased and improved, the added-value of the Copernicus programme would be boosted.**	2
Pillar III: ***Increase awareness***	***#FOR-5 - Increase capacity building programmes to better monitor deforestation and carbon emissions*** Many developing countries are currently actively participating in the REDD programme. In this framework, many are benefiting from value-added services based on EO-derived information in order to better monitor the impact of deforestation and carbon emissions. Thus, **in order for these programmes to be sustainable on the long-term, it is necessary for capacity building and training initiatives to be enhanced and widened in order for local authorities to gain the knowledge and competence to access, use and process EO data.**	2

Urban monitoring

Strategic pillar	**Sectoral recommendations for policy action**	**Priority level**
Pillar I: Ensure access to data	#UM-1 – Coordinate the relations and improve the dialogue between the different stakeholders Copernicus ecosystem is perceived as rather fragmented and thus difficult to approach by local authorities or SMEs operating in urban monitoring. Better coordinating the activities of the different institutions involved in the Copernicus programme would facilitate the access to the Copernicus data and services.	3
Pillar II: Support innovation	#UM-2 – Encourage partnerships between VAS companies Copernicus produces a huge volume of data so, in order for cities to maximise the benefits of such a programme, institutions could encourage partnerships of VAS companies to process and disseminate this data for urban monitoring applications.	3
Pillar II: Support innovation	#UM-3 – Communicate on the availability of Copernicus data to help monitor cities Having more visibility on Copernicus products to come (when they will be available, for which geographical zone, etc.) would help VAS companies to better anticipate the development of VAS products for specific towns.	2
Pillar II: Support innovation	#UM-4 – Create more synergies between EO-funded projects and ICT-funded projects Connections could be made between EO projects and ICT projects in the frame of smart cities in order to leverage synergies, identify the opportunities and create a flourishing market.	3
Pillar II: Support innovation	#UM-5 – Produce a standard processed data A standard processed data could help avoid duplicating the processing work among different actors. It would enable urban stakeholders to save time and budget and would facilitate comparisons between cities in the world.	2
Pillar III: Increase awareness and use	#UM-6 – Advertise EO applications for urban monitoring to the local authorities Organising a clear communication to local authorities on EO VAS benefits for urban monitoring and how to use such services could be a way to break cultural barriers, provide the right tools to maximise the benefits from such products and demonstrate how they lead to time and money savings.	1

Insurance

Strategic pillar	Sectoral recommendations for policy action	Priority level
Pillar I: ***Ensure access to data***	***#INS-1 – Build an "artificial history" for Sentinel data*** Most of the added value of the Sentinel data would come from index products, and the current barrier is the need for a long data history to be exploitable by the insurance sector. To accelerate this application, an investigation should be conducted on the technical means to constitute this history from the data available today and history of data from other sources.	1
Pillar I: ***Ensure access to data***	***#INS-2 – Support the creation of a platform oriented on insurers' customised needs*** As non-EO experts with specific needs, (re)insurers would benefit from a tailored access to EO data with a dual function: the manipulation of data to turn it into insurance inputs and the focal point of the different exploited sources, both open source and commercial.	2
Pillar I: ***Ensure access to data***	***#INS-3 – Centralise the open data sources to provide an open access service with increased responsiveness*** The interest in EO data for loss assessment strongly relies on the responsiveness after the event, which could be increased by mutualising several sources including the Sentinels.	3
Pillar II: ***Support innovation***	***#INS-4 – Stimulate the adoption of satellite images by initiating the trainings and information on key principles*** The current use of Copernicus remains very limited partly due to the lack of know-how on satellite images processes. (Re)insurers often rely on themselves (and the willingness of their people to take the "EO step") to become familiar with the existing sources, platforms, acquisition processes and technical knowledge on data format, manipulation and customisation. This know-how, though elementary, stands as a prohibitive barrier in some cases, and can be easily overcome, and is the opportunity to promote Copernicus by adapting the provided trainings to the Copernicus ecosystem. Some trainings on these principles would save a lot of energy, time and money for (re)insurers, which could then focus on their internal transformation.	1
Pillar II: ***Support innovation***	***#INS-5 – Support R&D works around index products to democratise their use*** The financial viability of index products for (re)insurers relies on the correlation between the index and the reality. This correlation represents a state-of-the-art knowledge about EO data, and tends to restrain both the interest of insurers in such products (reliability and cost) and the number of potential VAS companies providers (high expertise and cost).	2
Pillar II: ***Support innovation***	***#INS-6 – Clarify and ease the process to apply for EC grants*** The procedure to apply for EC grants and funds for Copernicus related initiatives is perceived as bulky, demanding in terms of time and energy, and lacking of transparency, especially for SMEs	3
Pillar III: ***Increase awareness***	***#INS-7 – Anticipate the storage and archiving responsibilities for Sentinel data*** The process and responsibilities for the storage and archiving of Sentinel data should be clarified in anticipation of the future use of the data by VAS companies and (re)insurers. This task is not perceived by insurers to be included within their scope.	2
Pillar III: ***Increase awareness***	***#INS-8 - Develop partnerships and collaborations between VAS companies and insurers*** In order to bridge the gap between the insurers' needs and EO experts' capabilities, partnerships should be encouraged. The aim would be both ensuring that the dialogue includes small actors and when necessary bringing financial support to the collaboration.	2

Ocean Monitoring

Strategic pillar	Sectorial recommendations for policy action	Priority level
Pillar I: Ensure access to data	#OCE-1 – Provide support to SMEs developing ocean-related applications for data access issues Micro-companies, SMEs or start-ups developing applications related to ocean monitoring do not necessarily have the financial resources to invest in the	2

	appropriate infrastructure to archive the important stream of data provided by the Sentinel missions. One possibility would be for the **EC to assist them in finding solutions to process and compute the available data.**	
Pillar II: Support innovation	#OCE-2 – Boost discussions between the EC and the private sector **The market for EO products related to ocean monitoring issues is yet not sufficiently mature.** Stakeholders from the private sector recommend increased discussions with their counterparts from the public sector and more specifically the EC in order for them to better respond to their needs.	1
Pillar III: Increase awareness	#OCE-3 – Increase the visibility of EO applications Ocean monitoring encompasses a wide range of sub-sectors (mapping fishing zones, monitoring illegal fishing, ensuring marine biodiversity, etc). Thus, many potential end users are not necessarily fully aware of the variety of services that their activities could benefit from. In response, **public authorities should strive for an increased knowledge and visibility of the applications and products** developed by service providers.	1
Pillar III: Increase awareness	#OCE-4 – Develop university courses There is a sound lack of technical knowledge regarding EO-related issues and oceanography. As a consequence, service providers can sometimes have difficulties in finding the appropriate resources with the relevant knowledge for their activities. The establishment of **specific university courses and technical trainings** could be a solution **to render EO mainstream in the ocean monitoring field**.	2
Others	#OCE-5 – Encourage international cooperation between ocean-related systems Stakeholders within the ocean monitoring field are in need of highly precise and accurate data, which cannot always be provided by satellit[2]e data. One solution would be to **boost international cooperation in order to establish a global and integrated vision of continental hydrological systems**, via for example multi-faceted programmes bringing together hydrologists, climatologists, river basin agencies, etc.	2

Specific recommendations for the **CMEMS**:

Others	**#OCE-6 – Integrate the CMEMS with the other Copernicus core services** **End users sometimes need highly specific data that is not always provided by the CMEMS. By being increasingly integrated to the other Copernicus core services, the CMEMS would be able to better respond to the needs of these users and provide them with the diversity of data they need (such as the waves height).**	1
Others	#OCE-7 – Help the CMEMS to contribute to the qualification of main trends Stakeholders from the ocean monitoring sector need precise information regarding main trends of the ocean. Thus, **the CMEMS should better contribute to the qualification of main trends and identification of major changes in the ocean**: today, the data provided does not enable to differentiate normal from abnormal phenomenon. In order to do so, streams of past data have to be processed, which is yet not possible for SMEs.	2

Oil and Gas

Strategic pillar	***Sectoral recommendations for policy action***	***Priority level***
Pillar I: Ensure access to data	***#OG-1 - Create more bridges between the Copernicus programme and the GIS virtual ecosystem*** O&G end users are integrating EO products into their GIS products. The Copernicus programme should continue pushing for the integration of the Sentinels data and products into the virtual GIS ecosystem such as the private platforms Arc GIS (Esri), Hexagon Geospatial (Hexagon AB), Geospatial Big Data Platform (Digital Globe) or Google Earth Engine (Google) for examples. Providing on these platforms tutorials and video capsules on why and how integrate Copernicus data & products into GIS products for specific O&G upstream activities can contribute strongly to Copernicus data dissemination.	1
Pillar I: Ensure access to data	***#OG-2 - Push for the development of more guidelines, trainings and white papers specifically designed for O&G exploration activities*** Beyond the physical access (via data warehouse or specific platforms), many O&G actors pinpointed the technicality as a barrier to access Copernicus data. More	

	specific guidelines, trainings and white papers on how to use Copernicus data and products in very specific O&G exploration or production activities are required. Tailored training on how to integrate Copernicus data with other sources of data should also contribute to facilitate non-EO experts to access, use and create value using Copernicus data and products.	2
***Pillar II*: Support innovation**	***#OG-3 - Increase collaborations between government, universities and the private industry*** Collaborations between universities and the private industry should be encouraged. Government can play this role of bridging those two worlds where universities are able to provide pre-commercial proof-of-concepts of usage of Copernicus data applied to specific O&G activities (publications, potential royalties). Industry is then able to push the concept to the market and derive revenues from it, using the products in their commercial activities.	2
***Pillar III*: Increase awareness**	***#OG-4 - Develop economic/business proof-of-concepts*** Many technical proof-of-concepts already exist for the use of EO data in the O&G upstream industry. To foster the dissemination of Copernicus data within the industry, organisations currently need proof-of-concepts on the business and economic side to demonstrate the type of cost reduction or gain in time and productivity enabled by Copernicus data in very specific O&G upstream activities.	1
***Pillar III*: Increase awareness**	***#OG-5 – Increase awareness within the industrial sector*** The largest share of benefits in the O&G upstream value chain is expected to come from end users and not from intermediate users. In this context, more awareness should be raised directly in the industry through presentations in O&G industrial conferences and the provision of tutorials and video capsules on specific O&G interfaces to stimulate awareness about the potential benefits of Copernicus data & products.	1

Renewable energies

Strategic pillar	***Sectoral recommendations for policy action***	***Priority level***
***Pillar I*: Ensure access to data**	***#RE-1 – Make the aerosol forecasts as easy to access as McClear*** The data should be made as available as possible for all kinds of users. Indeed, it can be fastidious for users to understand the catalogue of data and to download the right data. In particular, it is fastidious to access aerosol forecasts. However, McClear is quite easy to access.	3
***Pillar I*: Ensure access to data**	***#RE-2 – Make water vapour data available in near real time*** Today the water vapour is not available in real time in CAMS so McClear neither, it is available only sold by ECMWF. Not having the real time data makes the production of PV forecasts harder.	3
***Pillar II*: Support innovation**	***#RE-3 – Make available Sentinel-1 wind maps*** Producing wind maps is time consuming for VAS companies and research centres. It would make them save time if Copernicus could deliver ready-made wind maps. Wind maps are useful for forecasting wind turbines electricity production and making them available could enable the VAS companies to focus on the development of new value-added service.	2
***Pillar III*: Increase awareness**	***#RE-4 – Raise awareness of the impact of EO applications for wind farms*** Today, wind farm developers have a cultural barrier for adopting EO products and integrating them in their models whereas it has been proven that it improves the results. A communication campaign on the topic could foster the adoption of EO products among this type of actors.	1

Air Quality

Strategic pillar	***Sectoral recommendations for policy action***	***Priority level***
***Pillar I*: Ensure access to data**	***#AQ-1 – Keep improving the access to CAMS products*** The data should be made as available as possible for all kinds of users. Indeed, it can be fastidious for users to understand the catalogue of data and to download the right data.	3

***Pillar II*: Support innovation**	***#AQ-2 – Involve the research community in the development of CAMS*** The scientific research is fundamental for the development of CAMS in order to produce performant products, adapted to the market.	1
***Pillar II*: Support innovation**	***#AQ-3 - Invest on the development of inverse modelling services*** Inverse modelling is not fully operational with the current available Copernicus products. Many public and private actors need inverse modelling for developing new applications.	2
***Pillar II*: Support innovation**	***#AQ-4 – Include satellite data in national reportings*** National reportings should include satellite data for more comparability of the results and more transparency.	2
***Pillar III*: Increase awareness**	***#AQ-5 - Increase awareness on Copernicus in developing countries*** Developing countries and in particular Asia are a promising markets for air quality applications because contrarily to Western countries, there are less institutions taking in charge the analysis of air quality, leaving more room for the private sector. However, in Asia, CAMS is not very famous, (the awareness rate of Copernicus in Asia is estimated by one of the interviewees at 2%), the “National oceanic and Atmospheric Administration” (NOAA) for example is more famous. It would thus be interesting to design specific campaigns over the most promising areas.	1
Pillar III: Increase awareness	***#AQ-6 - Advertise CAMS to SMEs and provide training*** Today, most of the initiatives to increase awareness of CAMS and support SMEs are in France, and even in France the communication channels are too specialised to reach a non-expert audience. It would be interesting to communicate on CAMS through more main-stream channels of communication for SMEs and providing training on how to use CAMS products.	2
Pillar III: Increase awareness	***#AQ-7 - Advertise CAMS to the international organisations and public authorities*** Today, the main barrier to a market uptake in the field of air quality is not that CAMS is delivering free data, because it is possible to refine this data and sell it, it is that there are almost no citizen in the world willing to pay for Copernicus data, only few institutions are willing to pay for in-depth study of the Copernicus data. However, international organisations and public authorities should be the ones buying air quality for the citizens. The European Commission could have a role to play to demonstrate to these actors why they should use CAMS.	2
Pillar III: Increase awareness	***#AQ-8 - Advertise the national tenders at the European scale*** There is a lack of bidders on public tenders in the field of air quality, there are too few actors having the right capabilities to answer so it may be useful to advertise the national tenders at the European level to increase the number of potential bidders.	3
Other:	***#AQ-9 - Impulse a higher level of air quality control at the European level through policies*** Impulsing a higher level of air quality control at the European level could be done by implementing a polluter-payer principle and incentivising governments to monitor industrials emissions at their level. In Singapore, it is already the government who monitors industrial emissions.	1
Other:	***#AQ-10 - Better coordinate the climate and air quality policies*** Although climate and air quality are traditionally considered as different policy areas, an integrated or coordinated policy approach may lead to significant benefits and avoid trade-offs.	2

General recommendations

Nota bene: To identify these recommendations, the following methodology has been applied. In the frame of the series of interviews conducted by PwC-STRATEGY& with 80 users from 54 different entities, all comments expressed by interviewed stakeholders about the challenges, issues and opportunities of the Copernicus programme were listed. These remarks were then classified by thematic. For each category of user, only the most representative ones are displayed here, and ranked by priority level depending on their representativeness.

Legend:

	Low impact		Low priority level
	Medium impact		Medium priority level
	High impact		Strong priority level

- *Recurrence among users*: Priority level derived from the representativeness of Copernicus users' voice
- *Feasibility*: Ability to implement the recommendation
- *Financial Affordability*: Ability to be inexpensive
- *Quickness*: Ability to promptly implement the recommendation
- *Strategic impact*: Ability to contribute to the European space market uptake
- *Overall priority level*: Average level of priority according to PwC – Strategy& analysis

Main recommendations expressed by public intermediate users (sample=24)

	Stakeholders review		PwC – Strategy& Analysis				
Strategic pillar	***Transverse recommendations for policy action***	***Recurrence among users***	***Feasibility***	***Financial Affordability***	***Quickness***	***Strategic Impact***	***Overall priority level***
***Pillar II*: Support innovation**	***#PUB-1 – Prompt innovation through hackathons and demonstrators*** Today, the "killer app" which will revolutionise the market has not been found yet. **Hackathons and demonstrators still have to be organised to lead to viable applications.**	2					1
***Pillar I*: Ensure access to data**	***#PUB-2 – Address the non EO-literate users through dedicated tutorials*** EO data is mainly used by the scientific community as it is still difficult to manipulate. **The EC should provide basic tutorials to facilitate the undertaking of EO data by non EO-experts.**	3					1
***Pillar III*: Increase awareness and use**	***#PUB-3 – Focus on local authorities*** There is a lack of awareness from the local authorities. The EO applications could have a huge impact at local scale. **It could be relevant to classify the Copernicus data by territory and to gather feedback from such potential local users. The EC could also present best practice and examples to tackle local situations.**	3					2

Main recommendations expressed by private intermediate users (sample=52)

	Stakeholders review		PwC – Strategy& Analysis				
Strategic pillar	***Transverse recommendations for policy action***	***Recurrence among users***	***Feasibility***	***Financial Affordability***	***Quickness***	***Strategic Impact***	***Overall priority level***
***Pillar II*: Support innovation**	***#PRI-1 – Build common standards*** Private intermediate users are expecting **real-time data** and **a standard of low resolution processed**	1					3

	data furnished by the Copernicus core services to avoid duplications of basic computing work, save time and enable easy comparisons.						
***Pillar II*: Support innovation**	***#PRI-2 – Balance the open data communication*** The open data policy is key and enables to build disruptive products in viable business models but it can also threaten some commercial services. In the current digital trend, end users are now expecting applications and services for free and do not take into account the underlying added value work. **The wording of the institutional communication should take care on not creating confusion between open data and free enabled services.**	2					1
***Pillar I*: Ensure access to data**	***#PRI-3 – Simplify and harmonize the data access infrastructure*** Accessing Copernicus data is a significant issue. The multiplicity of access points does not ease the work of non-data specialists. Private intermediate users express that it is positive to have such a large choice. Hence, **the data access infrastructure should be harmonized and simplified in order to facilitate data access from end users.**	3					3
***Pillar III*: Increase awareness and use**	***#PRI-4 – Appeal potential end users*** Most end users are not aware of EO data potential. **A marketing campaign underlining the savings induced by Copernicus applications based on concrete case studies would be relevant.**	3					1
***Pillar I*: Ensure access to data**	***#PRI-5 – Propose data computation services on-line*** Due to its huge volume, the Copernicus data is complicated to process and to store, thus requiring large investments. **Providing basic on-line computation services will ease this issue.**	3					3
***Pillar II*: Support innovation**	***#PRI-6 – Create a data history*** The quality of the Copernicus data is reputed but some stakeholders do not use it because of a lack of history, which prevents from developing precise models. **Creating a data history with compatible and comparable data coming from past contributing missions would be a growth lever meanwhile the Sentinel one is being build.**	3					3

Main transverse recommendations expressed by users from micro-companies (sample= 7)

	Stakeholders review		***PwC – Strategy& Analysis***				
Strategic pillar	***Transverse recommendations for policy action***	***Recurrence among users***	***Feasibility***	***Financial Affordability***	***Quickness***	***Strategic Impact***	***Overall priority level***
***Pillar I*: Ensure access to data**	***#MIC-1 – Enhance the distribution of Copernicus data sets*** Micro-companies encounter significant difficulties to download Sentinel data sets compared to commercial data. **The distribution method, such as downloading specific pictures and not a whole data set, and the delivery channels might be redesigned. The creation of a standard data format could be considered.**	2					1

Main transverse recommendations expressed by users from SMEs (sample=32)

	Stakeholders review		PwC – Strategy& Analysis				
Strategic pillar	***Transverse recommendations for policy action***	***Recurrence among users***	***Feasibility***	***Financial Affordability***	***Quickness***	***Strategic Impact***	***Overall priority level***
Pillar II: Support innovation	***#SME-1 – Dispel doubts related to Copernicus long-term viability*** SMEs expressed their concerns regarding the durability of the Copernicus programme, the IP rules, the scale issue, the data storage, etc. **They are expecting clear signals from the EC on a long-term and clear strategy for the Copernicus programme in order to secure their products.**	1					2
Pillar II: Support innovation	***#SME-2 – Clarify and ease the administrative burden on H2020 calls*** SMEs are significantly losing time on the administrative part of the H2020 calls at the cost of the technical one. SMEs are also confused by the large topics proposed. **The EC should design more precise calls and present them as R&D levers, even if the proposals are not successful.**	3					2
Pillar II: Support innovation	***#SME-3 – Convince business angels to invest in Copernicus-based products*** Some SMEs in the EO market are only viable due to subsidies and public funds. **Campaigns should be conducted to encourage business angels to jump in.**	2					1

Main transverse recommendations expressed by users from large companies (sample=13)

	Stakeholders review		PwC – Strategy& Analysis				
Strategic pillar	***Transverse recommendations for policy action***	***Recurrence among users***	***Feasibility***	***Financial Affordability***	***Quickness***	***Strategic Impact***	***Overall priority level***
Pillar II: Support innovation	***#LAR-1 – Coordinate innovative initiatives among European stakeholders*** Cooperation between European stakeholders on innovative initiatives should be improved to remain competitive and be able to face global IT firms. **A coordination initiative supported by the EC could be useful to share breakthroughs (online forums, lessons learned, best practices).**	2					2

Main recommendations expressed by Copernicus end users (sample=14)

	Stakeholders review		PwC – Strategy& Analysis				
Strategic pillar	***Transverse recommendations for policy action***	***Recurrence among users***	***Feasibility***	***Financial Affordability***	***Quickness***	***Strategic Impact***	***Overall priority level***
Pillar I: Ensure access to data	***#END-1 – Insist on the durability of the Copernicus programme*** End users are expressing a confidence issue, wondering if the Copernicus programme will last on the long-term, which is an obstacle to a real economic take-off. **The EC should communicate**	1					2

	on the durability of the programme to reassure the market.						
***Pillar II*: Support innovation**	***#END-2 – Change the EO paradigm*** End users are not interested in the origin of the information; they just consider EO data as part of a larger ensemble. **In the current Big Data context, EC should consider the EO market through the ICT prism.**	2					1
***Pillar III*: Increase awareness and use**	***#END-3 – Federate new comers in the Copernicus community*** End users report a lack of understanding between their specific job issues and the EO experts. **The EC could set up workshops between the Copernicus community and potential end users. An exchange platform where end users post their needs and VAS stakeholders offer their expertise could be implemented.**	3					2
***Pillar I*: Ensure access to data**	***#END-4 – Propose capacity building solutions*** End users are not EO experts and they are asking for capacity building initiatives. **The EC could propose basic EO training based on MOOCs or a FAQ with a user-friendly interface where questions could be asked.**	3					1

Additional details on the Agricultural value-chain

Market trend

The market of downstream applications focused on agricultural issues is expected to grow. Many opportunities are yet unexploited and a study estimated that the forecasted EO Downstream Services Total Addressable Market (TAM) for the Agricultural sector amounted to approximately 0.4 billion euros in 2012.

The question remains on how the market should be organised – idea to establish European and /or international networks in order to put into contact SMEs providing valued added services – developing new products and applications is very costly and is not seen as the best option. In the coming years, the market will most probably be influenced by activities from large companies such as Google and Amazon but there should also be room for SMEs to fill the gap of certain individual scale of services.

Both public and private investments have significantly increased in the past few years, especially in emerging countries. Notably, China now spends nearly as much as the US in agricultural R&D[385] . Trends have shown in recent years increased collaboration between the private and the public sector with rising public-private partnerships.

Focus on innovative solutions to ensure sustainable projects based on EO data in Africa

One important issue in projects involving the use of EO data in the African continent is their sustainability on the long-term. Indeed, the respondents of the stakeholders' consultation leading projects in Africa have indicated sustainability as being one of the major threats of their projects – they encounter a lack of local experts as well as inadapted infrastructure.

In this context, the Netherlands Space Office (NSO), in collaboration with the Ministry of Foreign Affairs of the Netherlands, has launched an innovative programme "The Geodata for Agriculture and Water" (G4AW) aiming at stimulating partnerships and information services for food producers. This programme more specifically promotes and supports private investments for large scale, demand-driven and satellite based information services. The objectives of this initiative are the following: to improve the output of the agricultural, pastoral and fishing sector in 26 partner countries by providing food producers with relevant information, advice or products; to reach a minimum of 10% increase in sustainable food production and/or improved financial situation for at least three million food producers (ie. Farmers), by providing them with relevant and timely information services ; helping achieving a 10% more effective use of inputs for food production (water, seeds, fertiliser, etc.); focusing on sustainable improvement and increase of food production combined with a more efficient use of water in agriculture.

14 projects are part of this wide scale programme and concern over 70 organisations across 10 partner countries in South-East Asia, Africa and Latin America. The first call for proposals was launched in 2014, following which 4 projects were initiated. One particularly important criteria which was taken into account to select the countries and regions of each of these 14 projects was mobile connectivity: due to the lack of local infrastructure to access and process the data, the local stakeholders of the project send "ready to use" information on the mobile phones of farmers.

"Geodata for Innovative Agricultural Credit Insurance Schemes" (GIACIS) which more particularly aims at expanding financial service delivery to all smallholder farmers living in the highlands of Ethiopia. This project was launched 1, 5 years ago in four main provinces of the country: Oromia, Southern Nations, Nationalities, Amhara and Tigray. The project targets small scale farmers, 80% of whom have less than 0.5ha of land and who mostly

[385] KPMG. 2013. The agricultural and food value chain: Entering a new era of cooperation. [ONLINE] Available at: https://www.kpmg.com/US/en/IssuesAndInsights/ArticlesPublications/Documents/agricultural-food-value-chain-report.pdf. [Accessed 30 May 2016].

cultivate teff, wheat, barley, maize and sorghum. The objective of this project is to reach over one million smallholder farmers in 3 years.

This programme would not have been feasible without access to Sentinel data: indeed, the cost of privately-owned satellite images, as highlighted above, would have been too important for the programme to be economically viable.

Additional details on the Forestry value-chain

Additional information on overview of the forestry sector

Today, forests still cover almost a third of global land surface area, despite extensive deforestation in the past century386. Forests play a key role in the European economy and environment. European forests are exposed to many threats, be they natural or man-made. The assessment of damage becomes crucial in forest management activities.

The bio refinery sector is an emerging trend and plays a "key role to play in making energy production much more efficient, in creating second generation biofuels as well as new chemicals, products and markets, and thus in fulfilling policy goals that are being set"[387]. Examples of biotechnology techniques include: hemicellulose extraction from wood chips before pulping, lignin recovery from black liquor, methanol recovery from evaporator or digester condensates, biogas production from waste streams or sludge using anaerobic digestion, syngas generation from biomass using gasification, and bio-oil production from biomass using pyrolysis[388].

The forest-based sector is an innovative sector fit for the new bio economy. Its activities already fall under the European Environmental Agency definition as "providers of goods and services for environmental protection, including the provision of clean technologies, renewable energy, waste recycling, nature and landscape protection and ecological renovation of urban areas".

Focus on the Global Forest Observation Initiative (GFOI)

GFOI seeks to ensure a coordinated and continuous supply of satellite, ground and field data; improve the interoperability and integration of data from different sensors; promote coordinated research and development for improving national forest information systems; build capacity for accessing and using Earth observation data; coordinate the systematic provision of forest-carbon information and map products; and support continuing research and development. A GFOI Task Force and a Planning Team have been established to carry out this work.

The objective of the GFOI is assist countries to generate reliable, consistent and comparable reports on forest cover and forest cover change and to estimate forest carbon stocks and trends. This is vitally important for gaining a better understanding of whether forests around the world are helping to remove carbon dioxide from the atmosphere or are instead contributing to the problem of climate change[389].

Focus on Global Forest Watch (GFW)

GFW is a programme part of the World Resources Institute and has one main objective: making worldwide data on forestry open and available to all users globally. GFW was launched 3 years (5 years ago works in collaboration with 50 partners (including Google, Amazon, Landsat, etc) with a team of 30 people scattered around the world (Washington, Indonesia, Brazil, etc). GFW has a range of different services: websites, new data sets elaborated with universities and local partners as well as specific research. These services are all accessible for free and by all: they publish updated maps which are labelled monthly. GFW is funded by three main public entities: Norway, US and the UK as well as several stakeholders from the private sector (an investment company working in the agriculture business) and from foundations.

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[386] *ESA website. Consulted December, 9 2015.*
Link: http://www.esa.int/Our_Activities/Observing_the_Earth/Benefiting_Our_Economy/Forest_management
[387] *Forest-based sector technology platform, 2007. A Bio-solution to Climate Change, p.5. Link: http://www.forestplatform.org/files/FTP_biorefinery_report_part1.pdf*
[388] *Michael Paleologou, Theodore Radiotis, Lamfeddal Kouisni, Naceur Jemaa, Talat Mahmood, Tom Browne, Douglas Singbeil, 2011. New and emerging biorefinery technologies and products for the canadian forest industry.*
[389] *Group on Earth Observation, 2010. Launching the Global Forest Observation Initiative (GFOI). Link: https://www.earthobservations.org/art_011_003.shtml*

Focus on the OSFACO project

The OSFACO program began on March 14th and aims at consolidating the information gained from two projects as well as improve knowledge on past and present dynamics in terms of land occupation in the 8 1 recipient countries: (i) OSFT, where SPOT images covering 3 million km² of the Congo Basin territory have already been made available to over 70 recipient projects, and (ii) GEOFORAFRI, a project working on the reinforcement of capabilities and means for accessing satellite data and which already finances over thirty research projects in Central and Western Africa.

The French Development Agency (AFD) has provided 5 million euros for this programme, which is coordinated by the French institutions specialized in the field of spatial observation. The consortium created for the programme is led by IGN FI and includes the National Centre for Spatial Studies (CNES), the National Institute of Geographical and Forestry Information (IGN) and the Institute for Research and Development (IRD).

Satellite observation of the Earth is recognized as a key tool in measuring and tracking the evolution of land use, in particular for forest cover and agricultural areas, as well as for controlling the implementation and respect of land use policies.

High resolution SPOT images (up to 1.5 metres) provided by Airbus Defence and Space can also be used as tools to help render the use of forests as profitable and sustainable as possible (forest inventories, definitions for the limits of their use) as well as ensure that agro-industries develop in a responsible and sustainable manner (definition of zones with a high conservation value, definition of planting zones, verification of land licensee commitments, etc.). Satellite images along with land occupation data, are the basis for many applications designed for agriculture, land tenure, breeding, water resource management, land occupation, etc.
The ever-increasing demand for agricultural products (cacao, rubber and palm oil) has necessitated the development of sustainable land use and organization tools in order to ensure a system of agricultural development that poses no threat to forest conservation.

Satellite observation of the Earth provides a way for States with limited means to obtain specific and reliable data for very large surface areas in regions that are often difficult to access (tropical forest environments, no access by road, no means available to provide State personnel to perform random tests out in the field, etc.) on a regular basis and at low cost.[390]

[390] *Africabusiness. 2016. Signature of a funding agreement for the OSFACO project. [ONLINE] Available at: http://africabusiness.com/2016/03/30/signature-of-a-funding-agreement-for-the-osfaco-project/. [Accessed 22 June 2016].*

Additional details on the Insurance value-chain

Warning riverine floods through EFAS

What is EFAS and its mission

Within the European Commission's *Copernicus Emergency Management Service* (CEMS), the European Flood Awareness System (EFAS) was the **first early warning system to become operational, in 2012**.
The development of EFAS has been co-financed by several European Commission Services including DG ECHO, DG GROW, DG JRC and the European Parliament.

Its mission is to **increase preparedness for riverine floods across Europe**, by gaining time for preparedness measures before major flood events in particular for trans-national river basins. This is achieved by providing complementary probabilistic, flood early warning information up to 15 days in advance to its partners: the **National Hydrological Services** and the **European Response and Coordination Centre (ERCC)**.
Currently EFAS has **51 partners** out of which the majority are **national/regional hydrological/flood forecasting authorities and some are civil protection authorities**.

How it works

EFAS sends out **warning emails** to the corresponding EFAS partners in order to inform them that a possible flood event is approaching, using 3 levels of notifications towards its partners:

- **Formal flood notification** - when the probability of exceeding critical flood thresholds is forecasted more than 2 days ahead in a basin that has a minimum upstream area of more than 2000 km2
- **Informal flood notification** - when a probability of exceeding critical flood thresholds is forecasted in a river basin for which the forecasted event does not satisfy the rules of an EFAS Formal Flood Notification, e.g. regarding warning lead time, size of river basin, or location of event
- **Flash flood notification** - when the probability of exceeding a 20 year return period magnitude of the surface runoff index is forecasted to be greater than 35% and the forecasted start of the event is < 72 hours

The emails are, however, just a call of attention to the concerned EFAS partners. The user can then find more details on the EFAS web interface.

The support of EFAS to the **ERCC** includes 2 types of reports:

- a **daily overview** containing information on ongoing floods in Europe
- specific detailed analysis reports prepared upon request when large scale flooding is forecasted or ongoing : **10 reports prepared in 2015**

In addition, since October 2015 EFAS sends bi-weekly reports for the hydro-meteorological conditions of the principal **migration route of Syrian refugees.**

Access to EFAS real time forecasts is restricted to the EFAS partners to safeguard the one voice principle (as requested by the national authorities).

Users point of view on EFAS

Currently, EFAS has 397 registered users and the EFAS webpage has an average of **300 visits per month**. The geographical distribution of these visits is quite homogeneous over Europe.

The satisfaction of users on the overall EFAS system has been rated as "high" (4 / 5) in 2015. The trends underline a strong network, a valuable content of the bulletins but a format that should be improved, an adequate amount of information in the warnings and web services that have room for improvement.

Application case: May 2014 floods in Serbia / Croatia and Bosnia-Herzegovina

A preliminary version of the **rapid risk assessment procedure** has been tested on the catastrophic floods in May 2014, which affected the region around Sava River, between the confluence of Rivers Bosna and Drina, along with several minor tributaries.

The impact analysis has been limited to land use and population affected by flooding, excluding economic losses.
The EFAS forecast issued on May 13th for the Danube river basin has been selected to apply the mapping procedure. The flood hazard map (in blue) produced has been compared with a mosaic of the flood extent maps produced by the Copernicus Emergency Management System from satellite imagery (in red).

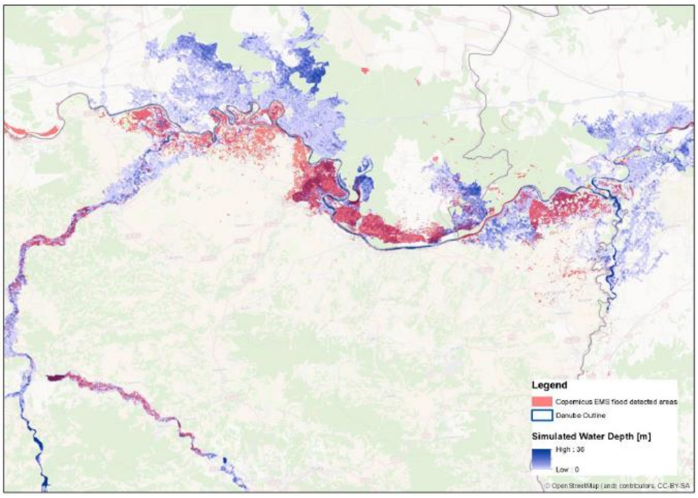

Figure 148 - EFAS forecast issued on May 13th for the Danube river basin

Predicted flooded areas are generally overestimating the actual flood extent: while the majority of observed flooded areas are actually included in the predicted map, large areas around the rivers Sava and Drina are indicated to be at risk, but were not affected.

The full operational implementation of this procedure is foreseen in the second quarter of 2016.

Barriers and enhancement of EFAS services uptake by public entities

1. EFAS services are only provided to EFAS partners, implying that an alert is **effective only if the affected area is locally covered by an EFAS partner**. For some countries such as e.g. Greece or Italy a large number of restricted information were sent out to the ERCC in Brussels, but no national centre was informed due to the lack of EFAS partner for that region. Those countries would particularly benefit of a future EFAS partnership.

2. Since 2015, 3 amendments were made to the EFAS Conditions of Access which should promote the use of EFAS products:
   - **Open the EFAS archive data**: all EFAS results and products older than one month are classified as non-real time and can be transferred to the EFAS archive which shall be open for the general public respecting underlying data licenses for distribution of data and derived products.
   - **Access to EFAS for Third Parties**: The EFAS Partner can formally nominate (propose) and revoke a Third Party in its area of responsibility who are also given access to EFAS products but have no vote at the Annual EFAS Partner meeting.
   - **Access to EFAS for research products**: The EFAS Partnership may invite a defined research project to access near-real time EFAS products for research purposes during a restricted and pre-defined period of time and after agreement of the EFAS Partners.

3. The usage of web services is rated on average as low (however those web services have only been introduced during 2014). To increase the use of EFAS web services a **specific training** could be envisaged as training on EFAS and its services is given high importance by the users.

Further applications of EFAS

Downstream applications based on EFAS data could be developed in the field of **agriculture** (e.g. monitoring and predicting the status of soil moisture), **renewable energy** (using hydrological forecasts to manage the production of hydropower) and **civil protection**.

An example for civil protection is the research project **Floodis** that developed an App to integrate Copernicus Emergency Services with satellite navigation and communication for establishing a mainstream oriented disaster alert and information platform for "flood events".

Additional details on the Ocean monitoring value-chain

Focus on the INDESO project

Indonesia has one of the biggest Exclusive Economic Zones (EEZ) in the world, which includes 2, 700, 000 km^2 of territorial and archipelago waters and 11 Fisheries Management Areas (FMA). The seas around Indonesia form part of the Coral Triangle, which encompasses the waters of Indonesia, Malaysia, Papua New Guinea, the Philippines, the Solomon Islands and West Timor. The Coral triangle is one of the most important reservoirs of marine biodiversity in the world. It contains some 30% of all coral reefs and the largest known tuna nurseries. Fishing, as an economic sector accounts for 3.5 million jobs in Indonesia.[391]

The INDESO programme (Infrastructure Development of Space Oceanography), offers an integrated solution to the challenge of monitoring and sustainable management of the marine resources in the Indonesian archipelago. The centre, based in Bali, comprises a receiving station for the acquisition of high-resolution radar satellite imagery, a research and surveillance facility, computing facilities including numerical models (e.g. for oceanic circulation, biochemistry, tuna populations) and a training department for scientists.

Its objective is twofold: preserving and improving the knowledge of Indonesia's marine biodiversity, with a focus on fish monitoring, and improving the measures necessary to adapt to climate change in order to establish sustainable fisheries and fight against illegal fishing.

The INDESO centre receives information related to seas and oceans from the Copernicus Marine Environment service. Indeed, the Copernicus global forecasting system monitors sea conditions such as temperature, salinity, sea levels and currents. The use of this data will enable the centre to reinforce and validate its numerical models for ocean and tuna population dynamics and biogeochemistry processes.

More than 25 satellites provide the INDESO centre with data on a daily basis. There are two types of satellites: low to medium resolution ocean observation satellites (1) which provide precise information on sea surface height and temperature, surface currents, salinity, surface winds, surface solar radiation: high-resolution radar (SAR) satellites (2)[392].

In the case of the INDESO programme, its centre is planning on using data from Sentinel-3 in order to measure sea-surface topography and temperature and ocean surface colour with high accuracy and reliability. Copernicus data collected via Sentinel-1 could also be used to enrich the information received on pollution and illegal fishing.

Focus on the Societal Applications in Fisheries & Aquaculture using Remote Sensing Imagery (SAFARI) project

The primary objective of the SAFARI Project is to integrate the activities of selected experts in fisheries and in Earth Observation (EO) to accelerate the pace of assimilation of EO into fisheries research and ecosystem-based fisheries management on a world scale. The proposed SAFARI Project will also help to build capacity on a global scale at the science level and the operational level, and will facilitate the application of rapidly evolving satellite technology to fisheries management questions.

The main components of the SAFARI Project are:

- International workshop on Enhanced Utilization of Earth Observations in Fisheries and Aquaculture, 26-28 March, 2008.
- Canadian remote-sensing information sessions - First half of 2009

[391] *AFD, 2015. Funding for a space oceanography infrastructure development project.*

[392] *Copernicus website. Consulted November, 26 2015.*

Link: http://newsletter.copernicus.eu/issue-09-february-2015/article/free-and-open-access-sentinel-1-and-sentinel-3-data-would-contribute

- IOCCG Monograph on Applications of Remote Sensing in Fisheries and Aquaculture - Second half of 2009
- International Symposium - First half of 2010

Earth observation has a great deal of potential to benefit society under activities covered generally under the heading Fisheries and Aquaculture. Various EO initiatives related to fisheries have already been started outside the umbrella of GEO, and it will be extremely useful, under GEO Task Number AG-06-02 to coordinate these at the international scale, and add to their value through synergy.

Further, the international consensus to follow ecosystem-based management raises the imperative to design and implement a suite of ecological indicators with a view to detecting change in the ocean ecosystem should it occur in response to perturbations, for example by climate change or by overfishing. Such indicators would also be responsive to seasonal and interannual changes in the ecosystem, and thus be of use to fisheries research and management. Because of its high resolution in space and time, and low incremental cost, EO by remote sensing will be of the utmost importance in this regard.[393]

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Additional details on the Oil and Gas value-chain

Macro-economic context of the O&G industry

The macro-economic context of the O&G industry is currently very negative. Oil price has declined on the similar order of magnitude than post financial crisis, losing 72% of its value in two years. The figure also shows the context of the project EO4OG earlier discussed and we can observe that the price of oil has collapsed since the end of the initiative in June 2014. As earlier highlighted, the O&G industry is led by the price of oil, so when price is low, the industry reduces drastically it investment in exploration and drilling. This context has very negatively affected the penetration rate of EO products in the O&G industry, including the ones using Copernicus data.

A strong reduction of the price of oil can be compensated by a strong increase in consumption. However, the O&G demand is strongly inelastic which means a reduction of price does not lead to an important increase in consumption. Figure 149 shows the demand of O&G, this market is very mature with very low Compound Annual Growth Rate (CAGR). The CAGR over the last period under scrutiny in Figure 149 2013-2014) shows even a CAGR inferior at 1%.

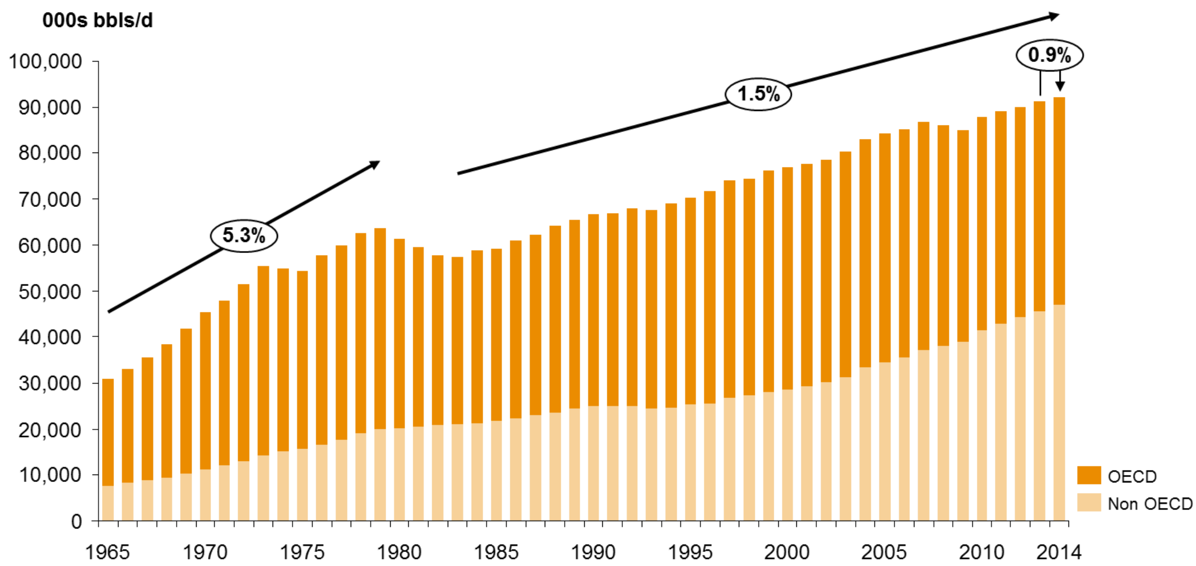

Figure 149 - Global oil demand worldwide, OECD vs. Non OECD (Sources: BP Statistical Review of World Energy, June 2015; Strategy& analysis)

A very low barel's price and a stagnant demand has a strong impact on a very risk averse industry. Figure 150 shows the overall yearly CAPEX spend in Exploration & Production. The CAPEX represents the investments made in tangible infrastructure, which is a very important indicator of the health of the market in the O&G upstream. The worldwide CAPEX has lost 22% on the period 2014-2015 and 12% on the period 2015-2016, indicating the industry is curbing investment.

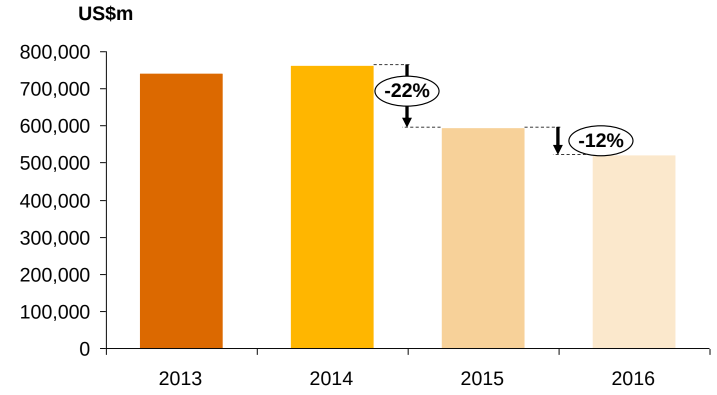

Figure 150 - Global Exploration & Production Capex Spend (2013 - e2016) (Sources: Rystad Energy, Strategy& analysis)

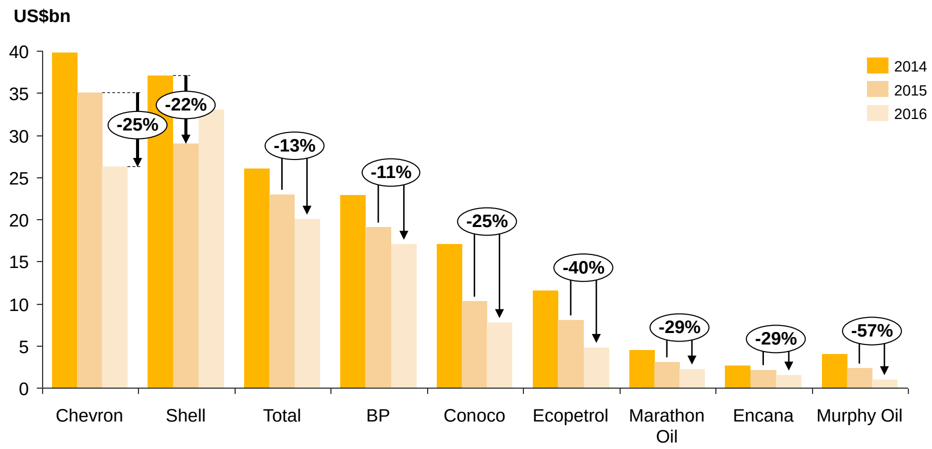

Figure 151 - CAPEX announcements since 2014 (Sources: Bloomberg; Press; Strategy& research)

The O&G upstream in Europe is following the same trend as indicated in the table below. The overall market has declined for all the actors on the last period. The collapse is even bigger for the Exploration & Production which has faced a negative growth rate of - 79,39 % from the period 2013-14 to 2015-16.

(M EUR/ Europe)	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16
Integrated actors	475,821	512,974	498,983	543,970	499,157	445,348
Exploration & Production	44,403	48,400	47,180	42,703	27,770	8,798
Refining & Marketing	10,944	8,482	9,190	11,243	10,859	8,641
Storage & Transportation	12,196	12,171	16,233	19,629	24,058	16,345

Table 63 - European upstream market (Sources : Bloomberg, Strategy& analysis)

Assessment O&G: Estimate of current size of the overall market and forecasts

All the figures used in market assessment (not including the revenues related to EO or Copernicus) are based on Bloomberg, Rystad Energy and public documents (companies annual statements, industry surveys, etc.)
The figures related to the use of EO data and Copernicus per type of actors are derived from the case study and based on stakeholder consultation.

Large integrated actors

Using large integrated actors annual statement, data from Rystad Energy and Bloomberg: Exploration (survey, planning, drilling, safety) for these actors represents 5.91% of their overall activities.
Overall European integrated actors: EUR 445,348 B

Exploration = 5.91% X 445,348 = EUR 26.32 B
From interviews: revenues derived from EO data on the exploration are ranging between 5 and 8%
5% was taken in order to insure minimal estimation
Exploration revenues derived from the use of EO data (2015) = EUR 1,316 B
Currently, the use of Copernicus is not widely spread but some Copernicus products, especially for off-shore monitoring, are used and Sentinels data are available in several O&G GIS products. The interviews and the survey have estimated the use of Copernicus data on the overall imagery-based revenues to be equal at 4.25% (average among responses).
Exploration revenues derived from the use of Copernicus data (2015) = 1,316 X 4.25% = EUR 55.93 M
However, Landsat is used a lot (10% of the imagery) and Sentinel-2 will be able to substitute Landsat in the next 5 years (higher spatial and temporal resolution). Using a stable revenues derived from EO data within large integrated actors – even if it is very unlikely revenues derived from imagery is not growing over the next 5 years. We have derived the following table:

CAGR					
2015	**2016**	**2017**	**2018**	**2019**	**2020**
4,25%	5,00%	7,00%	7,70%	8,90%	10,00%

The upstream revenues derived from the use of Copernicus data by 2020 is expected to be EUR 131.60 M (per year).

Oilfield services

EUR 8,798 B (not fully reported), we can estimate the fully reported year will lead to around 14 B (based on discussions with O&G market analyst, Rystad Energy data and Bloomberg). From the interviews and our survey, 8.65% the revenues (in average) are based on imagery. We have taken the minimal estimation to insure robustness.
Exploration revenues derived from the use of imagery (2015) = 14 X 8.65% = EUR 1,211 B
Currently, usage of Copernicus data vary a lot from one actor to another. For most of oilfield service companies, they are starting to incorporate Copernicus data in their products (in most of the cases GIS products). Our sample is biased by one extreme value of an oilfield service company having already developed an offer based mostly on Copernicus data for exploration in deep-frozen areas. For all the other companies, the average use of Copernicus data among their imagery sources is equal to 3.75%.
Exploration revenues derived from the use of Copernicus data (2015) = 1 211 X 3.75% = EUR 45.41 M
Landsat is used a lot (13% of the imagery) and Sentinel-2 will be able to substitute Landsat in the next 5 years (higher spatial and temporal resolution). Using a stable revenues derived from EO data within large integrated actors – even if it is very unlikely revenues derived from imagery is not growing over the next 5 years. We have derived the following table:

CAGR					
2015	**2016**	**2017**	**2018**	**2019**	**2020**
3,75%	4,00%	7,00%	8,59%	10,65%	13,00%

The upstream revenues derived from the use of Copernicus data are expected to be EUR 157.43 M by 2020 (per year).

Other O&G actors

O&G refining & marketing actors were excluded because this type of actor was not interviewed and there is no proof of Copernicus usage. To insure robustness, this category was excluded.
O&G storage and transport actors were not interviewed since they are considered part of the midstream industry. Literature has highlighted the use of EO data, potentially Copernicus data, for pipeline monitoring and pipeline development. Such actors are also using intensively GIS products which includes imagery so it can be interesting to look at these actors in a future study.

Environmental monitoring companies

No data available, this category was excluded to give a minimal estimation, insuring robustness of analysis.

Intermediate users for O&G only: EO downstream actors

We have used EARSC figures as a proxy. In 2015, O&G represents EUR 73 M. Stakeholder consultation has led to an estimation of 8% being based on Copernicus data and products.

Exploration revenues derived from the use of Copernicus data (2015) = 73 X 8% = EUR 5.84 M
The average CAGR expected over the period 2015-2020 in EO imagery is 12.63%. This calculation is very conservative since the proportion of revenues derived from Copernicus data (currently estimated around 8%) is expected to grow significantly in the coming years. Starting from EUR 5.84 M in 2015 with a CAGR of 12.63% over the period 2015-2020, the conservative market estimation for O&G actors based on Copernicus only should be EUR 10.585 M in 2020.

Intermediate users for O&G only: GIS actors

The process to isolate the contribution to Copernicus data & products to GIS products tailored for O&G end users was done as followed.
The overall market for GIS in EMEA based on Technavio market report is US$ 3 211 M, which corresponds to EUR 2 893,111 M (currency exchange: US$ 1 = EUR 0,901). Only Europe represent 91,5% of this sample: EUR 2 647,20 M.

Only GIS data & services market are directly impacted by the free availability of Copernicus data and products, which accounts for 50,5% on the European overall GIS market: EUR 1 336,83 M.

Natural resources represent in Europe 12,80% of the GIS revenues: EUR 171,11 M.

The International Energy Agency consider oil and gas to represent 32,4% + 21,4% = 56,8% of the overall natural resources. Based on this value, we estimate the GIS data and services market for O&G upstream to be EUR 97,19 M.

If we consider the proportion of contribution of Copernicus data & products for intermediate users (EO downstream) to be roughly the same than intermediate users (GIS), we can assess:
2015: 97,19 X 8% = EUR 7,78 M

Techanvio has assessed the CAGR for GIS market in Europe for the "Natural Resources" users. We have taken these figures as proxy, O&G being the main contributor to natural resources revenues, that we have applied on the enabled revenues

	2015	2016	2017	2018	2019	2020
CAGR expected [394]	N/A	10,10%	10,15%	10,19%	10,27%	10,32%
Enabled revenues by Copernicus per year (EUR M)	7,78	8,57	9,44	10,40	11,46	12,65

[394] *Source: Technavio, 2016. Global GIS market 2016-2020.*

Additional details on the Air Quality value-chain

Achieving COP21 targets thanks to Copernicus

Reporting needs after COP21

After the EO data has proven that global warming was the result of the human activities, EO will play a key role in monitoring the achievement of the different targets set at national or international levels for greenhouse gases reductions, and in particular for those set in the framework of COP 21[395]. It brought together 195 countries that developed and signed a universal agreement: the **United Nations Framework Convention on Climate Change**. In parallel, 188 countries published their **Intended Nationally Determined Contribution (INDC)** that will be renewed every five years.

The convention's main objective is to limit "the increase in global average temperature to well below 2°C [...] and to pursue efforts to limit temperature increase to 1.5°C above pre-industrial levels" and to get the emissions "peak as soon as possible". Even if COP21 engagements are not constraining, they will be controlled and countries will have to report on the progress, in particular, **the countries will have to start reporting on the INDC on the "global stocktake" every five years from 2023**. The emissions and removals have to be accounted for according to methodologies and common metrics assessed by the Intergovernmental Panel on Climate Change (IPCC), set up by the World Meteorological Organization and the United Nations Environment Programme. The countries also have to provide data and services to feed the IPCC special report that will be put in place in 2018.

Why Copernicus is key in monitoring the achievement of the targets

The European Commission points out that the use of space-based assets should be considered in mitigating and adapting to the climate change, and in particular through **monitoring and surveillance of greenhouse gases (GHG) emissions** in its report *" Towards a new international climate agreement in Paris (2015/2112(INI))"*, where it specifically mentions the Copernicus programme.

According to this report, EO can:

- Support stocktaking methods to measure the anthropogenic emissions of GHG through applications such analysis of the atmospheric composition or land use
- Support mitigation measures thanks to applications such as land use or its contribution to programmes such as REDD+
- Support adaptation measures by providing local geospatial data
- Provide historical data to support the definition of risk factors and indicators and assess the effect of policies
- Support "loss and damage" via information on disaster risk reduction and management
- Enhance further research on climate change

Copernicus is a key programme for providing **data on atmospheric composition**, in particular, **Sentinel-5P, Sentinel-4 and Sentinel-5 will provide data to monitor trace gases concentrations** (gases that represent less than 1% of the atmosphere) **and aerosols**, but it does not include CO2 emissions measurements.

Copernicus also provides and will provide the required historical data for scientists to keep on doing research on climate change but also for decision-makers to be able to assess the effect of their policies. In particular, the ECMWF (European Center for Medium-Range Weather Forecasts) has been delegated by the European Commission the coordination of the **Copernicus Atmosphere Monitoring Service (CAMS) and of the Copernicus Climate Monitoring Service (CCMS)** that will provide near real time analyses and forecasts of the atmosphere composition and of the climate global evolution. CAMS is already running but for CCMS only a few products are available today as it is still under development.

[395] *The COP 21 is the last United Nations Climate Change Conference that was held in Paris at the end of 2015 that aims at mitigating and adapting to climate change*

Copernicus also provides all the necessary data to **monitor land use in order to support mitigation and adaptation measures**. For example, in Europe, **UrbanAtlas** is a platform of the European Commission initiative that provides a pan-European comparable land use and land cover information for large urban zones based on Copernicus data.

Towards a European monitoring of fossil CO2 emissions in the frame of Copernicus?

There are still capabilities required in order for Europe to monitor with precision the achievement of its targets. Indeed, **so far Copernicus will not measure the atmospheric CO2, but the needed capabilities are being assessed for a possible new satellite** in the frame of the programme. It comes out that the needed capabilities are the following:

- Dense sampling (imagery), in order to be able to identify plumes produced by emitting areas
- High spatial resolution in order to capture emission hotspots and avoid clouds (pixel size of less than 3km)
- High accuracy, in order to resolve the atmospheric gradients (individual precision of 1 ppm)
- Global coverage

Current CO2 emissions inventories are based on self-reported statistical data collected for the entire territory where emissions occur. Despite the efforts to improve these inventories by each country, the global fossil CO2 emissions are becoming more uncertain due to the increasing contribution of less developed countries. Moreover, these inventories have other limitations such as the fact that they are difficult to control, limited in scale given the limited granularity of the economic data and they require considerable infrastructures and technical capacity.

The UN Subsidiary Body for Scientific and Technological Advice (SBSTA) specifies the **need for space-based measures of atmospheric CO2 concentrations,** and insists on the need for assimilation and re-analysis of data. Thanks to Earth Observation, it is possible to **use together the top-down and the bottom-up approach in order to have a global measurement of atmospheric CO2** and mapping them through the use of the national and regional inventories. These top-down CO2 measurements are produced in two phases: first a dense sampling of the selected emissions hotspots, such as cities or industrial areas, is analysed based on column CO2 measurements; then, the fossil CO2 component is separated from the natural fluxes at regional scale.

Almost all of the existing satellite missions are not designed to quantify emissions but natural fluxes, with 2 exceptions:

- NASA's OCO-3, that takes repeated images over hot spots
- ESA's CarbonSat that was designed to take images with a 250km swath.

Sentinel satellites could ensure the continuity of these measurements and propose new useful measurements. The addition of these services to the **Copernicus programme**, under assessment, would make it the **key programme for monitoring and verifying the compliance of parties to international climate agreements such as COP 21**.

How to boost uptake from public authorities (best practice from ECMWF)

The stakeholders interested in monitoring the achievement of targets such as COP21's are **public actors like national governments, regional authorities or environmental institutions**. Private actors may also want to access such information, for example it can be the case of sectorial industry players that aim at complying with the regulation, consultants with specific expertise, etc.

In order to boost uptake from public authorities in the field of achieving such targets, there are several possible levers:

- Launch **communication campaigns** to communicate on the existence, the efficiency and the benefits of using such tools. This is what is done by ECMWF that for example launched a communication campaign and organized a workshop at the COP21
- Collect **user feedback** as the ECMWF is doing for the European Commission by storing the user feedback for their atmosphere and climate products
- Ease the **access to the data**, as it has regularly been reported in ECMWF's user consultation as a barrier to the use of the atmosphere and climate products
- Provide **large data sets**, as requested by the scientific community that needs to reanalyze it for building models.

The Copernicus World Alliance (CWA) overview

Initiated at the 4th Ground Segment Coordination Body (GSCB) Workshop on the 24th of September 2015 at ESA-ESRIN (Frascati, Italy)[396], the Copernicus World Alliance (CWA) is gathering more than 30 European industry stakeholders[397] developing web-services already addressing, originally derived from, or of potential benefit to the Earth Observation (EO) sector for:

- Helping the EO community to tackle the challenges coming from the digital economy
- Supporting EARSC initiative for creating a MarketPlace for EO Services[398]
- Promoting INFOrmation as a Service (INFOaaS) based on EO data and services
- Bringing value to public and private end users willing to pay such services

CWA is open to European industry stakeholders addressing Earth Observation (EO) Services, willing to contribute and sharing the same vision and objectives which are the following:

- Working together overcoming fragmentation, at the EU level
- Joining European forces : EO Services (EARSC) and ICT (BDVA, EGI, Helix Nebula)
- Demonstrating that European industry is able to deliver to public and private entities « INFOrmation as a Service » (INFOaaS) derived from Earth Observation
- Leveraging EURB 7+ EU & ESA investments related to Copernicus & Sentinels
- Testing value chain(s) and business model(s)
- Pulling the market by stimulating demand

One service among several already operated by CWA is the SUD Service designed and operated by EOproc for the back-end and Sinergise for the front-end.

Rationale

The idea of this service came out of a discussion between Daniel Quintart (EC DG GROW Space Data for Societal Challenges and Growth) and Emmanuel Mondon (AdviceGEO) at the 2016 Conference on Big Data from Space (BiDS)[399] jointly organised by ESA, SatCen, and JRC in Santa Cruz de Tenerife, Spain, from 15 to 17 March 2016.
One month later, the service has been released and demonstrated live at the Copernicus Value Chain Workshop, held on 26th and 27th April 2016 in Brussels.[400]
This service is available to everybody willing to know statistics and metrics related to the Sentinels Scientific/Other use Data API Hub access points provided by ESA[401], including :

- Coverage of the last day/10 days/1 month
- Product ingest rates for S1/S2/S3 - granularity: 1h floating average over 24h
- API availability and observed typical query response times - granularity: 5 min floating average over 1h
- Delay in hours between data acquisition and ingest to the data repository respectively availability, aggregated to delay groups

[396] Link: https://earth.esa.int/documents/1656065/2066722/19-GSCB-Workshop-Session-2-Presentation-CloudEO-AG.pdf
[397] Link: http://cwa.infoaas.eu/indexpartner.html
[398] Download related EARSC Position Paper here
Link: http://earsc.org/file_download/308/EARSC+PP+-+Creating+a+European+marketplace+for+EO+services.pdf
[399] Link: http://congrexprojects.com/2016-events/16m05/introduction
[400] Link: http://www.copernicus.eu/value-chain-workshop
[401] Link: https://scihub.copernicus.eu/

Partners

AdviceGEO

AdviceGEO was created in February 2016 by Emmanuel Mondon, as a "boutique" that provides specialized services for the Geospatial & Earth Observation (GEO) market, helping this particular segment to tackle the digital (r)evolution. The GEO community, like all the other communities, is deeply impacted by the digital economy. In fact, for Geospatial & Earth Observation, we should speak about a revolution, rather than an evolution, as the required changes generated by the digital economy represent a real paradigm shift.
AdviceGEO is currently coordinating CWA activities and being involved in the EARSC Study supported by ESA related to creating a European MarketPlace for EO Services.

EOproc

EOproc is a young company, founded in 2013 by Dr. Martin Lange, providing more than 10 years of expertise in geospatial web services and innovative Geo-IT. With a heritage of spaceborne and airborne sensor data processing, EOproc decided early to transition its know how of GIS-processing to virtualized, distributed, manageable and scalable architectures at datacenter level, nowadays called the "cloud". Along with the change in technology, the business focus shifted from traditional one-off monolithic GIS projects to Geo-interoperability and professional, sustainable Geo-IT-web-services from simple REST-APIs over Geo-Factories for fully automated elastic and scalable Geo-data-number-crunching to full featured platforms, on which users can consume and process Geo-data to their needs without the need for physically owning them. One example of services provided by EOproc is SatCat (available on www.eoproc.com), a free and open web portal, allowing users to search for EO data of various satellites like Sentinel or Landsat in a unified way.

Sinergise

Sinergise was established in 2008 to develop enterprise-level solutions for managing spatial data, especially for support in land administration and agriculture processes. These are based on one of the first world-scale distributed GIS editing frameworks, Giselle. In its years of operations Sinergise built solutions for large governmental clients in Europe (United Kingdom, France, Slovenia, Croatia, Macedonia, Montenegro, Czech Republic, Azerbaijan, Moldova) and Africa (Nigeria, Ghana, Tanzania, Mauritius). Altogether there are more than 2 million people annually using Sinergise's tools and its technology helps to manage more than 50 million property records and more than 500 million EUR of transactions annually.
Sinergise developed Sentinel Hub (http://www.sentinel-hub.com) - a real-time processing of satellite imagery, currently supported Sentinel-2 data. Service queries the scenes meta-data for appropriate scenes in the area of interest (filtered by cloud coverage, time period, etc.), downloads relevant data from the archive, creates a mosaic and composite and, if requested, rendering such as true color, color infrared, NDVi, etc. These steps take 2-4 seconds and are exposed to users as OGC standard web-services (WMS, WMTS, WCS, WFS). Processing is done on original JP2 files, which makes the service extremely cost efficient.

SUD Key Features

The Sentinel User Dashboard (SUD) provides highly current online information to regular users about data availability on the public data hub of the Sentinel satellites. It also provides a graphical display of the trend lines of the metrics, in order to put the current numbers into a broader mid-term context.
The SUD is addressing institutional stakeholders and service providers, routinely consuming EO data from Sentinels Scientific Data Hub.
Data access and availability are challenging at complex operational, high volume systems like the Sentinels Scientific Data Hub and the availability of current and accurate metrics are fundamental to evaluate and improve the system. The SUD is providing this metrics from the perspective of a user, accessing the Sentinel EO data.
These metrics are:

- Availability and typical response times for API calls to the Sentinels Scientific Data Hub
- Current and historical 24 h data production rates of Sentinel-1 and 2
- Current and historical timeliness of EO data (time between data acquisition and availability at the Data Hub)

The metrics are intended to provide answers to the following questions, which are of particular importance to service providers:

- What is the current and average data production rate of the satellite systems and at the Sentinels Scientific Data Hub?
- What is the variation of data production, which downstream services need to handle? Respectively, how elastic do the downstream services need to be?

- What expectations on data availability, respectively what service level agreement can the downstream service provider forward to his customers ?
- Is the data production running at normal / average levels or is the Data Hub encountering an anomaly?
- What is the timeliness of the data from the Data Hub?

Technical facts, figures & outlook

Technically the SUD comprises a monitoring engine, designed and operated by EOroc and a web server front end, designed and operated by Sinergise, both collaborating partners within the CWA. The SUD monitoring engine constantly queries the Sentinels Scientific Data Hub every 5 minutes on all three currently active APIs (dhus, apihub and s2) and stores the results in a database. At same 5 minute intervals a SUD report is aggregated, which is then retrieved by the Sinergise web portal. The current set of SUD metrics are a first starting point for an objective, independent evaluation of Sentinel data production from a user´s perspective.

Numerous extensions of the SUD are in the pipeline, depending on users demand, such as:

- API for querying machine to machine the current Data Hub status (percent of long term average). This service would help service providers to identify if the source of anomalies is on the Data Hub side or on the service provider side
- Timely notification to service providers and users based on SUD metrics.
- Qualified and independent metrics allowing service providers to distinguish between the availability of their service and the availability of Data Hub input data.
- Metrics for Sentinel production versus acquisition time (rather than ingestion time). This is of interest for long term EO observations, which do not care about data timeliness, but continuity of data acquisition.

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