European Commission

COPERNICUS

Market report

November 2016

Prepared by PwC for the European Commission

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Space

Copernicus
Europe's eyes on Earth

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Luxembourg: Publications Office of the European Union, 2016

ISBN 978-92-79-59009-2
DOI: 10.2873/827100
Catalogue number: ET-01-16-623-EN-N

Printed in Belgium

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Contents

Note: This Market Report summarizes the main findings from two studies, prepared by PwC for the European Commission and published in 2016: (1) *The report on the Copernicus downstream sector and end user benefits*, and (2) *The report on the socio-economic impact of Copernicus*. The interested reader will be able to find a wealth of additional details in these two studies.

Copernicus: Europe's eyes on Earth

Elżbieta Bieńkowska

European Commissioner
for Internal Market, Industry,
Entrepreneurship and SMEs

If we are to respond to the challenges of sustainable consumption of natural resources, guarantee safety and security, and understand the causes and consequences of climate change, we need to better know the state and health of the environment.

The Copernicus programme is a cornerstone of the European Union's efforts to monitor the Earth and its diverse ecosystems, whilst ensuring that we are prepared and protected in the face of a natural or man-made disaster. But Copernicus can also drive economic growth, because it can act as a data source for applications and services. It is a symbol of European strategic cooperation in space research and industrial development.

The images and data from a constellation of satellites and in-situ components are used by a wide range of economic sectors with applications in precision farming, civil protection and insurance, oil & gas exploration, meteorology or urban monitoring, to name just a few. Sales of data, value added services and applications related to Earth Observation, are undergoing a remarkable growth with an average annual rate of more than 13%. The close link between satellite images and the wider geo-information products sector reinforces the strength of these downstream markets. The increasingly central role of Big Data is leading to the downstream development of commercial activities.

After consultation with a wide range of stakeholders, 8 selected economic sectors have been assessed for the current and future impact of Copernicus on their businesses. After only a year in operation of the first Sentinel satellite, Copernicus intermediate and end users are already seeing economic, social, environmental and strategic benefits to their activity. All expect this to continue in the years to come. As announced in the Space Strategy for Europe, over the coming years the Commission will set the conditions to build on these encouraging results by ensuring the continuity of the Copernicus programme, giving access to space data and continuing to foster innovation in the downstream sector.

We are on the road to making Copernicus a great European success!

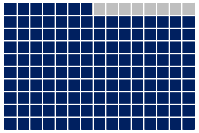
Earth Observation stakeholders consulted (interviews performed during the first semester of 2016)

INSTITUTIONAL STAKEHOLDERS

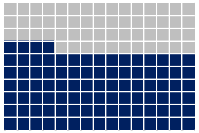
- Aerospace Valley
- Big Data Value Association (BDVA)
- Centre National d'Etudes Spatiales (CNES)
- Daithi O'Murchu Marine Research Station (DOMMRC)
- Deutsches Zentrum für Luft- und Raumfahrt (DLR)
- DTU Wind Energy
- ESA
- EU-Japan Centre for Industrial Cooperation
- Eurisy
- European Association 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

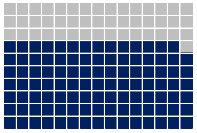
- Airbus Defence and Space
- Amazon Web Services (AWS)
- Atos
- Axa
- C-Core
- Collecte Localisation Satellites (CLS)
- CS Communication & Systèmes
- Deltares
- DigitalGlobe
- Elecnor Deimos
- ESRI
- GAF
- Google
- Groupama
- Hatfield Consultants
- Orange
- Planet Labs
- RHEA Group
- RPS Energy
- Swiss Re
- Willis Re



142
persons interviewed



94
different entities



104
participants in the Copernicus survey

MICRO-COMPANIES

- AdviceGEO
- Building Radar
- Earth-i
- Gaia
- Geocento
- i-Sea
- Nazka
- Pixalytics
- Viridian Raven

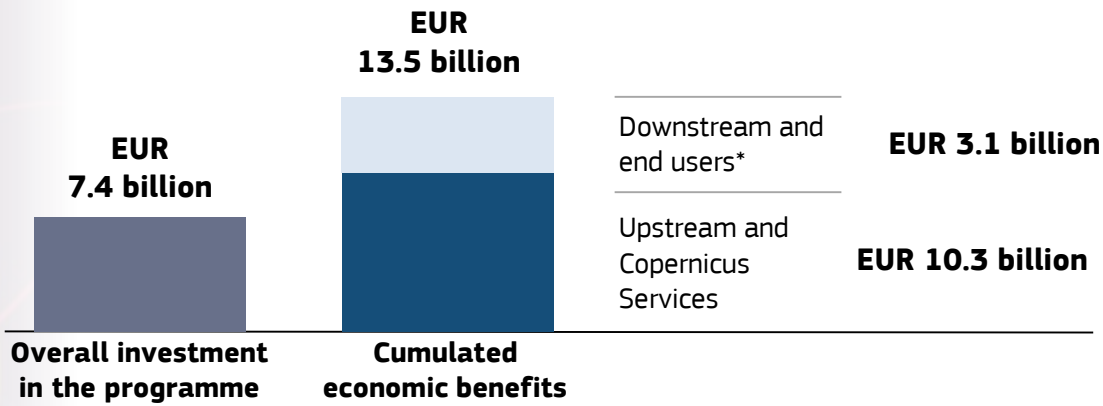
SMEs

- 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

Overview of Copernicus programme benefits

From 2008 up to 2020, the total investments in the Copernicus programme are forecasted to reach EUR 7.5 billion. Over the same period, this investment will generate a benefit of 13.5 billion (not counting non-monetary benefits). This economic value is generated through the added value created in the upstream space industry, the sales of Copernicus-based applications by downstream service suppliers and the exploitation of Copernicus-enabled products by end users in various economic sectors..

Cumulated impacts over 2008 - 2020



12,450 job years supported in the downstream and end user markets

15,580 jobs years supported in the upstream

Examples of existing Copernicus benefits

70% Cost reduction of a precision farming service in Austria, thanks to Copernicus

€ 60k Yearly savings for each construction company using a work progress monitoring app

60% Higher accuracy for analysis of the impact of trans-boundaries pollutants on air quality

5% Productivity gain for fish farmers, by monitoring toxic algal blooms

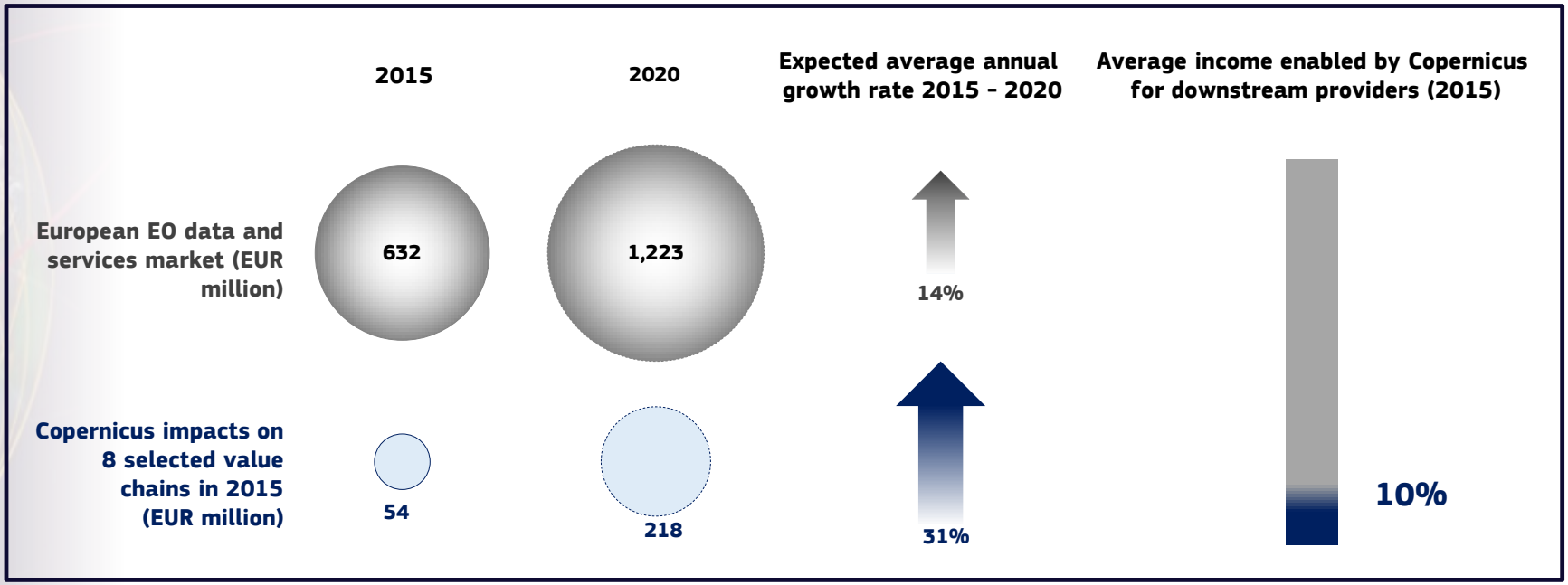
50% Copernicus-based forecasts generate 50% more benefits to solar energy producers than traditional forecasts

€ 186M Benefits of Copernicus on the insurance market in 2015

* The Downstream and end user analysis includes only 8 value chains: Agriculture, Forestry, Urban Monitoring, Insurance, Ocean Monitoring, Oil & Gas, Renewable Energies and Air Quality. Estimates for end users were only calculated for Insurance, Oil&Gas and Urban Monitoring. The estimates of downstream and end user benefits should be seen as extremely conservative because they were calculated barely a year after the launch of the first Sentinel satellite. Benefits are likely to increase significantly as more Sentinels become operational and as users progressively discover the programme. In addition, the end user benefits (which are likely to be substantially larger than the downstream benefits) were only calculated for the commercial users in three value chains (Insurance, Oil&Gas and Urban Monitoring). Many user benefits are non-monetary in nature and extremely complex to quantify. The aim of this study was to have the most robust figures in order to show the existence of the phenomenon rather than providing an exact figure (to prevent overestimation of benefits).

Overview of intermediate users' benefits (1/2)

Intermediate users constitute the main link between Copernicus and the community of potential users of Copernicus-enabled products and services. **Also designated as downstream providers, they are typically service providers** processing raw data to turn it into exploitable information for end users. In 2015, the benefits of Copernicus in the downstream market are estimated between EUR 28 and 54 Million. They are expected to grow at an impressive 31% per year. Today, the main barriers to the growth of these markets are low willingness to pay among end users (e.g. for Air Quality products), the gap between end users' specific needs for tailored products and available solutions (e.g. Insurance), or the still recent adoption of EO-based products in general in the market (e.g. Renewable energies).



66 %
Proportion of EO companies exploiting **Copernicus data** in Europe

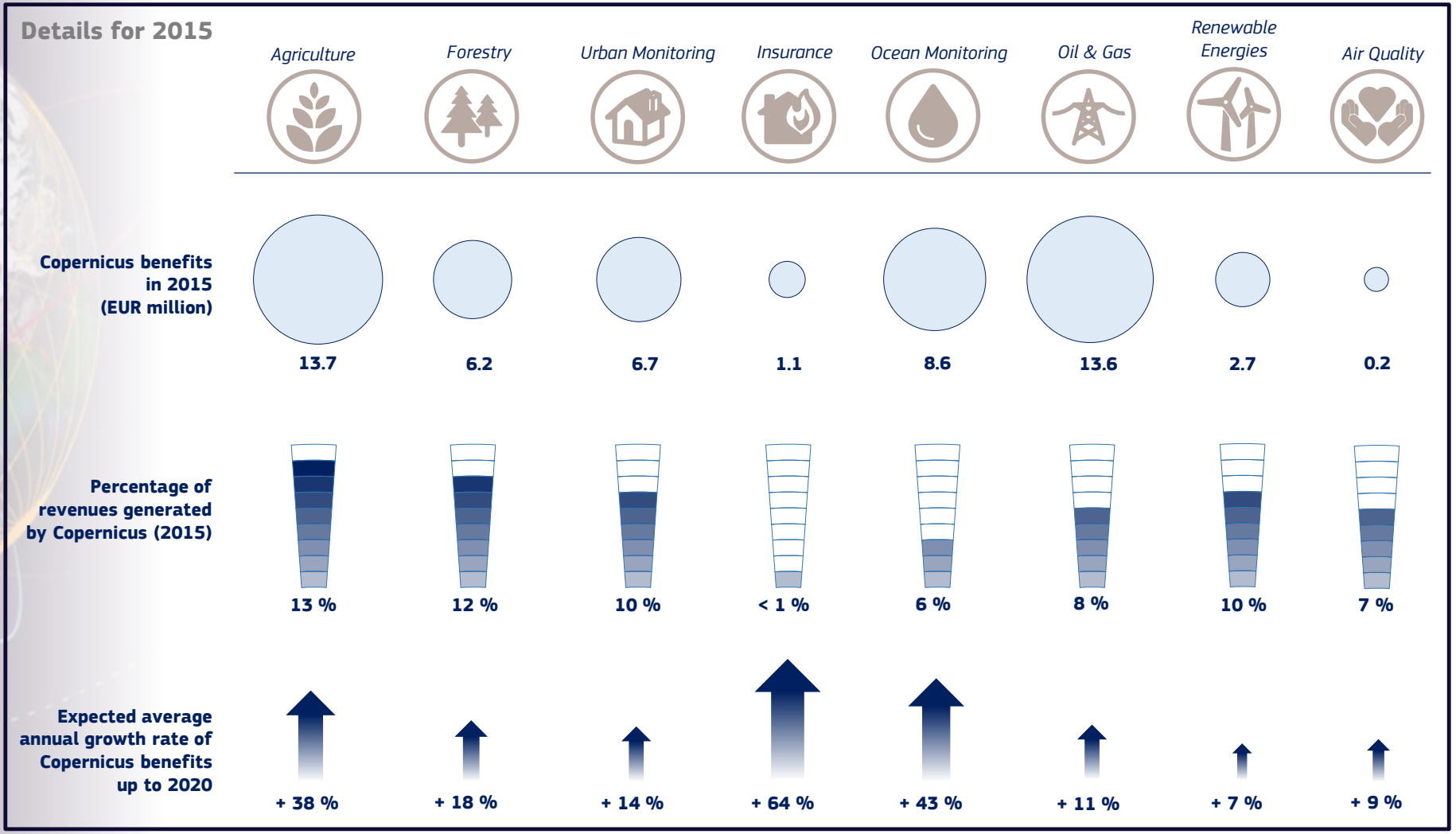
27 %
Proportion of EO companies exploiting **Copernicus services** in Europe

8 million
Copernicus products downloaded on the Sci-Hub (September 2016)

51,000
registered users in the Sci-hub (September 2016)

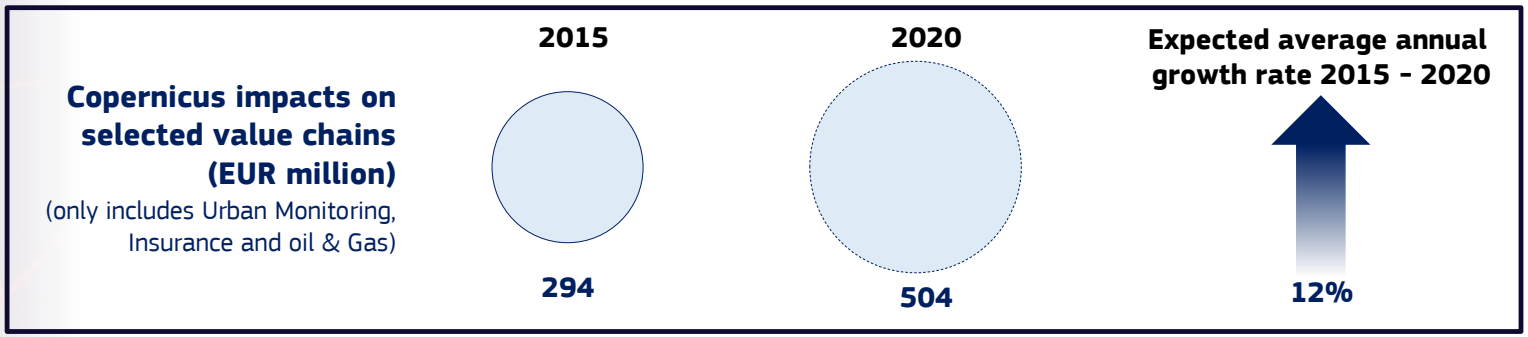
Overview of intermediate users' benefits (2/2)

The Copernicus benefits vary between the value chains, depending on the relative size of the domain in the EO downstream market and the penetration rate of Copernicus. All the sectors considered are forecasted to witness a positive evolution of Copernicus economic impacts and some value chains are expected to experience very high growth in the coming years (particularly Agriculture, Insurance and Ocean Monitoring).



Overview of end users' benefits

End users' benefits are generated either through the exploitation of Copernicus-enabled products provided by intermediate users or through direct use of Copernicus data by non-EO players. End users represent potentially much larger markets than the EO / GIS downstream markets, and so could potentially show 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.



Key findings

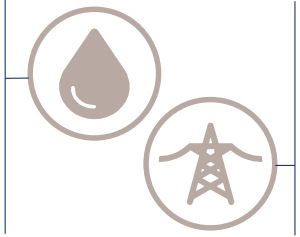
Historically one of the first domains to exploit EO, **agriculture** is the most promising market in terms of the impact of Copernicus, especially through precision farming. The intermediate users have various profiles, from start-ups and SMEs to large companies and purely scientific players. It is also the market with the highest penetration rate of Copernicus, which already enables 13% of the revenues of the sector. Though not quantified here, Copernicus' contribution to farmers' business can be expected to be substantial, considering the strong influence of EO on precision farming technologies.

Depending on the country, **forests** may be owned mainly either by public or private entities. As with agriculture, Copernicus intermediate users have different profiles, and Copernicus enables a substantial share of their revenues, estimated at close to 12% on average. End users, by contrast, are mostly public bodies and few commercial applications exploit forestry EO-based products, making it difficult to quantify end users' benefits.

Urban Monitoring offers a wide span of applications for EO and hence for Copernicus. Intermediate users are mainly SMEs, operating in a well-developed market of which Copernicus already enables about 10% of the revenues. Urban Monitoring products are expected to benefit from the high growth of smart cities markets, and hence the influence of Copernicus should keep increasing. The majority of end users are local authorities, which often face budget constraints to develop the use of innovative products such as EO, but which show encouraging trends.

For **natural disasters insurance**, intermediate users' benefits 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. This leads either to an in-house handling of EO raw data by the end users who can afford the infrastructure, or to a decision not to use satellite images which are regarded as a non-critical source of data. Index products represent a potential market for intermediate users, but Copernicus constellation is too young to be exploited. End users' benefits can potentially be much higher, considering the high amounts involved in natural disasters insurance.

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, which results in a lower penetration of Copernicus data, around 6%. Sentinel-3 is expected to strongly impact the benefits of Copernicus for ocean monitoring applications.



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

Renewable energies 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 out of which Copernicus represents 10% of the revenues.

Air Quality information and applications only recently started to make use of EO data, being traditionally based on meteorological data, statistics and measurements. Intermediate users are mostly environmental and meteorological agencies, or publicly-funded organisations. Indeed end users' needs tend to be addressed by public authorities as individuals demonstrate low willingness to pay for information or products on Air Quality.

EARTH OBSERVATION MARKET

In a nutshell

- Earth Observation (EO) technologies are used to monitor land, marine and atmosphere from space with various remote sensing technologies.
- The European EO market is valued at between EUR 2.1 and 2.4 billion, divided between EO satellite operations (the upstream part of the supply chain), EO data acquisition and storage (the midstream part), and EO data processing to provide value added services to end users in many different sectors (the downstream part).
- In Europe, the EO upstream segment is valued at EUR 1.6 billion which represents 64% to 76% of the revenues of the European EO economy. The revenues of the European EO Services industry (midstream + downstream) amounted to EUR 911 million in 2015.
- The global EO downstream market is valued at EUR 2,8 billion in 2015. It is expected to grow to EUR 5.3 billion in 2020, at an annual growth rate of 13%. The European market share, estimated at EUR 632 million in 2015, is growing.
- The EO downstream market is undergoing strong trends through vertical integration, Unmanned Aircraft Systems and cloud computing.
- The main innovation in the EO downstream market is the implementation of platforms. This will drastically change access to the data over the coming years.
- EO 2.0 players are entering the market with an innovative approach. These stakeholders, vertically integrated, have in-house capabilities to manufacture satellites but also to handle the data and develop and offer services.
- Lessons learned from the Landsat programme are fundamental to support the creation of a real space ecosystem in Europe.

Overview of Earth Observation

What is Earth Observation?

Earth Observation (EO) refers to the use of remote sensing technologies to monitor land, marine (seas, rivers, lakes) and atmosphere.

Satellite-based EO relies on the use of satellite-mounted payloads to gather imaging data about the Earth's characteristics.

The first essential parameter for EO technologies is the type of information provided:

- **Passive remote sensing:** the satellite's remote sensing payload monitors the energy received from the Earth due to the reflection and re-emission of the Sun's energy by the Earth's surface or atmosphere. 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 from the Earth's surface or atmosphere, enabling day and night monitoring during all weather conditions. Radar and lasers are commonly used active sensors.

The second essential parameter in EO is the sensor resolution:

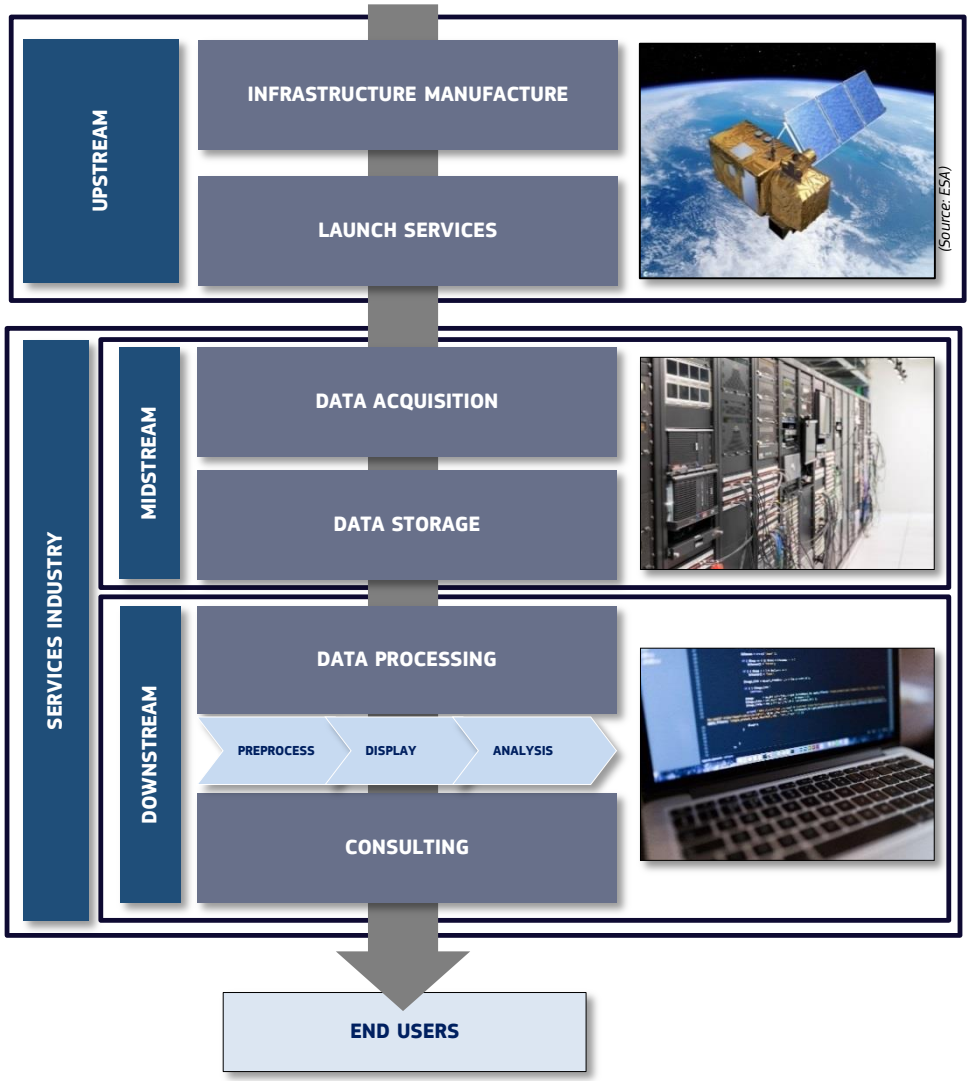
- **Low and medium resolution**: more than 10 meters per pixel;
- **High resolution:** between 2.5 and 10 metres per pixel;
- **Very-high resolution (VHR):** less than 2.5 meters per pixel. The use of VHR imagery with a higher resolution than 0.3 meters is subject to restrictions that limit it to government applications.

€ 2050 to 2410 million[1]

Revenues of the European Earth Observation Economy in 2014

European Earth Observation Economy

(Source: PwC-Strategy& analysis)



Nota Bene: The structure of the value chain depends on the taxonomy adopted: the traditional taxonomy segments the value chain between Uptream / Midstream / Downstream while the EARSC taxonomy segments it between Upstream / Services Industry.

[1] *Source: Eurospace, 2015. Facts & Figures. & PwC-Strategy& analysis*

Key statistics for the Earth Observation upstream segment

The EO upstream segment

The upstream sector includes:

- EO satellites and ground segments manufacturers
- Launch services providers
- EO payloads manufacturers
- Space agencies' EO programmes

In Europe, the revenues from EO upstream activities are estimated around EUR 1.55 billion in 2014. This includes, after consolidation, space institutional budgets and manufacturing industry revenues for the space segment.

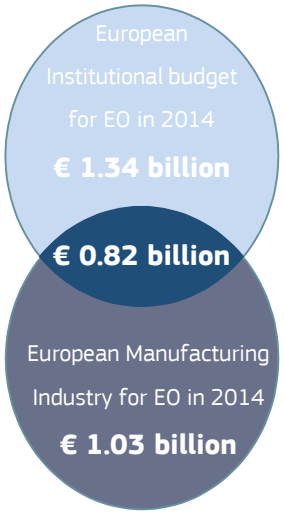
In 2014, sales of Earth Observation space systems by the European Space manufacturing industry reached EUR 1.03 billion, representing about 17% of all European space systems manufacturing revenues.

The EO space systems market is mostly domestic with 80% of revenues coming from European sources.

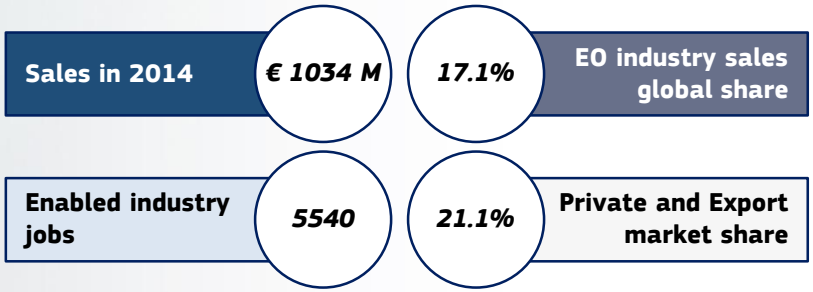
In Europe, the EO upstream segment values

€ 1.55 billion

which represents 64% to 76% of the European EO economy.



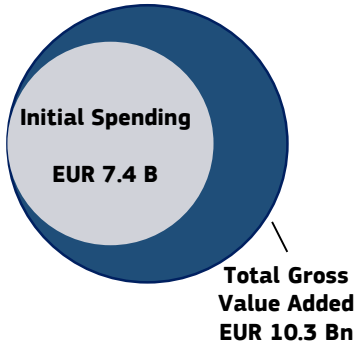
European Earth Observation space segment industry indicators in 2014 *(Source: Eurospace, 2015. Facts & Figures)*



The Copernicus upstream segment

For the **Copernicus programme**, around 60% of initial spending is retained in the space sector as Gross Value Added (GVA), and the remaining 40% flows down the supply chain to non-space sectors. The **overall value added generated by this spending is estimated at about EUR 10.3 billion**.

Impact of investment in the Copernicus programme
Period 2008 - 2020



For 1€ spent by public funds in Copernicus upstream activities, the value added in the whole economy is 1.4 €.

Employment impact of Copernicus upstream investments

Over 2008-2013, the Copernicus programme generated **additional employment in the European industry equivalent to about 15,580 person years**. Most of this impact is felt in the space sector (which is typically high-skilled) with 11,750 person years, but the increase in the space sector demand for goods and services also generated additional employment along the supply chain equivalent to 3,830 person years.

Government revenues

In addition, the Copernicus programme generated **government revenues** corresponding to income tax, taxes on products and employees' social security contributions, representing a cumulative total **around EUR 1.5 Billion** over 2008-2020.

Key statistics for the Earth Observation downstream market

What is the Earth Observation downstream market?

The EO downstream market includes all the actors involved in the exploitation of EO data, providing EO-related products and services to end-users. For end users, the value of the EO data lies in the products and services that make use of it.

The EO downstream market includes in particular Value Added Services (VAS) companies and geo-information companies, developing products that exploit EO data. In the sectoral value chains analysis these actors are termed **intermediate users**.

A EUR 5.3 billion global market in 2020

The EO data and value added services market has been growing steadily over the past decade, reaching **EUR 2.75 billion in 2015**.

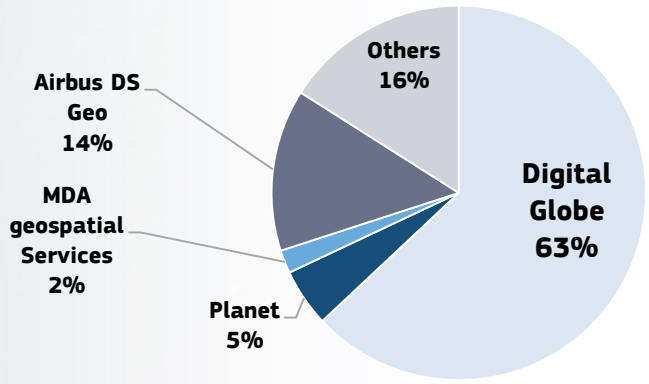
Data Sales and value-added services are expected to keep rapidly expanding in the coming decade, reaching **EUR 5.3 billion by 2020,** with a Compound Annual Growth Rate (CAGR) of more than 13% over 2014 – 2019.

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 market in the coming decade, as already witnessed for instance with Amazon Web Services and its open data pilot project based on Landsat data.

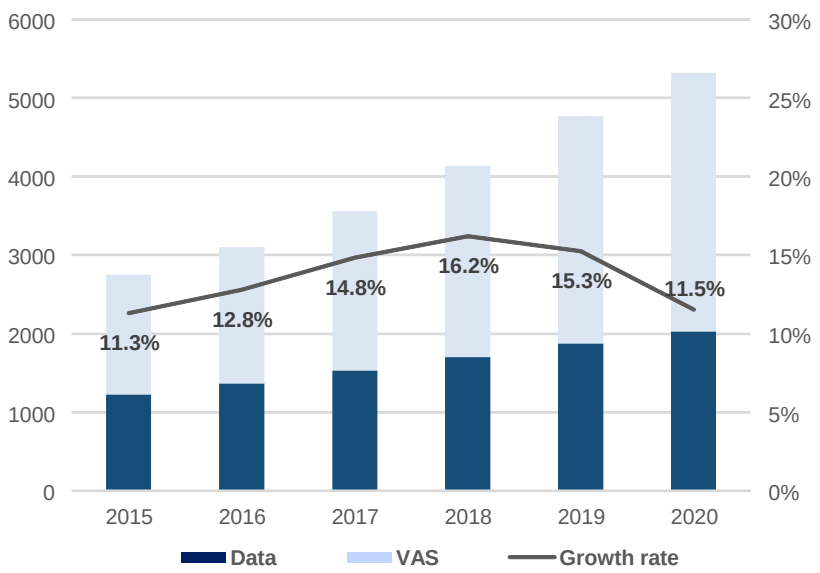
VAS are expected to expand widely in the next 5 years

The variety of EO data creates tremendous commercial opportunities, across sectors from agriculture to fishing, through construction and transport, oil & gas, renewable energies, or insurance, boosting economic growth in general. The emergence of numerous new players, mainly Small and Medium Enterprises (SMEs), will support job creation in the market.

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



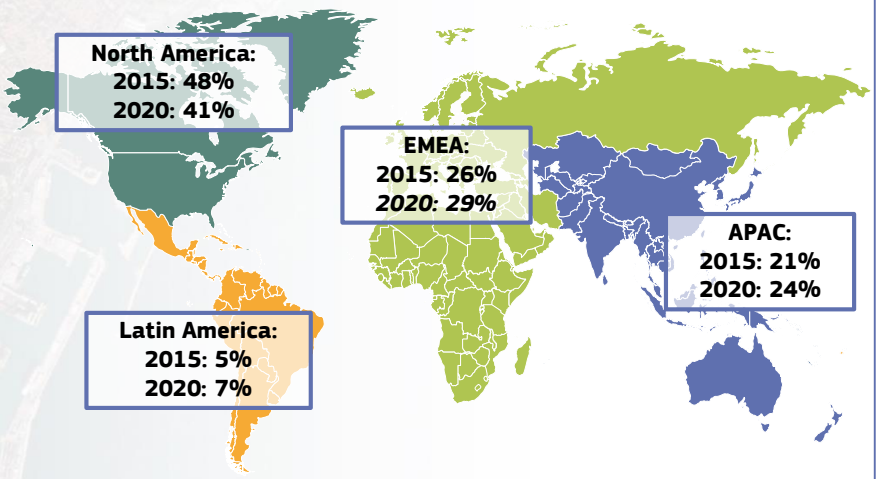
Commercial data sales and value-added services worldwide from 2015 to 2020 (in EUR Million)
(Source: adapted from Technavio, 2015. Global Satellite-based Earth Observation Market, 2016-2020)



Earth Observation downstream market shares

Global satellite-based EO market by geographic area 2015 – 2020

(Source: adapted from Technavio, 2015)



Global satellite-based EO market by vertical segment 2015 – 2020

(Source: adapted from Technavio, 2015)

Defence & Intelligence
- 2015: 36%
- *2020: 33%*

Energy
- 2015: 8%
- *2020: 9%*

Weather forecast & meteorological apps
- 2015: 11%
- *2020: 12%*

Agriculture
- 2015: 7%
- *2020: 9%*

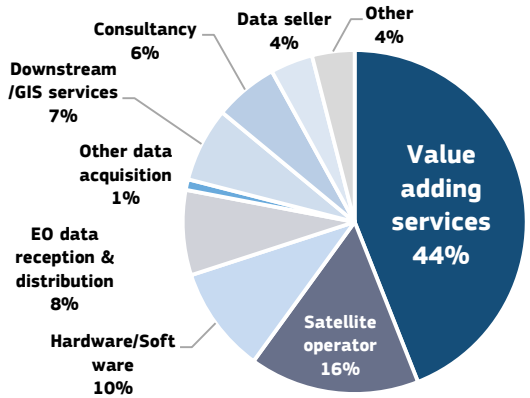
Location-based services
- 2015: 10%
- *2020: 9%*

Insurance
- 2015: 6%
- *2020: 7%*

€ 2,751 Million[1]
Global EO downstream market in 2015

€ 632 Million[1]
European EO downstream market in 2015

€ 911 Million[2]
European EO Services industry (midstream and downstream) in 2015



Split of European Services Industry (Source: adapted from EARSC, 2015)

[1] *Source: Technavio, 2015. Global Satellite-based Earth Observation Market, 2016-2020. – Conversion rate: 2015 average rate: 0,9019 (European Central Bank)*
[2] *Source: EARSC, 2015. A Survey into the State and Health of the European EO Services Industry. Prepared by EARSC, under assignment from ESA. September 2015.*

Trends in the EO downstream market

Trend #1 – The GIS market as a growth opportunity

A Geographic Information System (GIS) is a "computer information system that can input, store, manipulate, analyse, and display geographically referenced (spatial) data to support decision-making processes"[1]. It allows spatial data to be combined with other types of data and so EO data can be one of the sources. Hence the GIS market encompasses the EO market. Technavio estimates the **GIS market** to be **around EUR 8.8 billion in 2015**.

Satellite-based and airborne EO data are the heart of GIS products and services. GIS providers **combine this core imagery with other sources (in-situ data, navigation signals, social media information** etc.), creating very high-value-added products for end users.

The strong growth of the GIS market should be seen as a potential opportunity for growth for EO downstream players (intermediate users) if they manage to adapt well to a market in which there are multiple sources of data.

*The leader in the GIS platforms market for Oil & Gas is the **ArcGIS** platform, developed and operated by the US company Esri. The company has captured between 80-90% of GIS platform sales to the Oil and Gas industry.*

Trend #2 – EO 2.0 players are promoting stronger competition

Space start-ups are emerging in the imagery market. This is correlated with the surge of **constellations of small satellites**, which differ from traditional large EO satellites by their **low cost** for access to space and hence to EO products, and the delivery of **near-real-time images**.

These new players are called EO 2.0 actors, often closer to the IT industry than the space sector. They are targeting very high resolution imagery (mostly optical) with a very high tasking capacity compared to traditional players. The growth of EO 2.0 actors should promote the development of a **mass-market for very high resolution imagery** in near real-time in the future.

Trend #3 – Cloud computing

Cloud computing is a new way to access data that facilitates large-volume storage. **Users do not need to download and store the data on their own hardware**, reducing the cost of access. It gives users access to a wide range of different sources of data with a unique entry point.

There is strong competition among cloud providers such as **Amazon Web Services (AWS), Google, Microsoft, Oracle or IBM** and this is helping to bring down the costs of storage.

Trend #4 – Unmanned Aircraft Systems (UAS)

The data provided by **drones** are very useful for small and local area surveys, providing **very high resolution imagery** that are complementary, rather than substitute, to Copernicus-like data.

Trend #5 – Open data EO programmes

Nowadays, publicly-owned EO programmes tend to provide open and free-of-charge EO data, such as the well-known Landsat programme, or the European initiative, Copernicus.

An open data policy gives all types of users **access to free, low and medium spatial resolution data with interesting temporal resolution**. This acts as a game changer for numerous applications across many economic sectors related to agriculture, oceans economy, oil & gas, air quality, insurance or smart cities, for instance.

[1] *Source: GIS Map Info website: www.igismap.com/gis-geographic-information-system*

EO downstream platforms

The platforms era

The last component of the EO downstream market, the **platform**, only represents a tiny fraction of the EO downstream market, but EO downstream experts estimate that **the strongest growth is expected to come from this type of activity in the future**.

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**. These cloud-based platforms support on-demand analysis and the exploitation of synergies between multiple data sources.

Innovative platforms initiatives

To be able to provide digital platforms, very powerful ICT infrastructures (storage, distribution, etc.) are required in the midstream industry. Large ICT players and data companies have entered the market in recent years, such as Google, Amazon Web Services or Microsoft. These ICT players are facilitating the emergence of a new digital market for EO data, and for Big Data and Geo-spatial information in general.

Downstream players build analytics platforms on the top of these infrastructures in order to provide the interface that enables the visualization of data (APIs). Most of them also offer on-the-cloud processing. A large number of players in the US EO downstream market have already started developing their own platform and some of them already offer some services and on-the-cloud processing, such as Digital Globe or Planet Labs.

Different ways to access EO data

TASKING

- Scene approach ($/km2)
- On-demand services
- Very specific demand
  - Geographic coverage
  - Spatial resolution
  - Sensors
  - Specific timing
- Near-real time data included in this category

ARCHIVES

- Scene approach ($/km2)
- Usually interested in change detection over time
- Long series of data
  - Geographic area
  - Comparable data (archive continuity)
  - Comparable "timing"

PLATFORM

- Tile approach ($/time)
- Digitalisation of the economy & Big data paradigm
- On-the cloud and on-demand analysis
- New approach, still under development

The Google Earth Engine makes use of remote sensing imagery, mostly based on Landsat and airborne data. Sentinels data are also now being incorporated in the platform.

The Google Earth Engine has over 8,000 users on which approximately 2,300 are located in Europe. Of these European users, 1,100 belong to more than 290 different universities. Sentinel-1 has over 200 users, with over 25,000 scripts run on the collection. The Google Earth Engine expects a much higher usage of Sentinel-2 data when it is available on the platform.

COPERNICUS MARKET

In a nutshell

- The Copernicus programme is the **European Union's Earth Observation flagship programme.** From 2014 to 2020, the European Union (EU) will commit **EUR 4.3 billion to Copernicus.**
- Through its set of components that collect data from various sources – **EO satellites (the Sentinels) and a multitude of in situ sensors** on the ground, at sea, or in the air – Copernicus responds to the needs of its users – European citizens – in their daily lives through
- **Copernicus has six thematic services (Land, Marine, Atmosphere, Climate, Emergency and Security)** supporting the development of many applications. The Copernicus services process and analyse the data, integrate it with other sources and validate the results.
- Copernicus gives users **free, full and open access to data and services. Copernicus is the 3rd largest data provider in the world**, with 8 Petabytes per year.
- The **Copernicus** programme provides data and services that support **added value in several non-space domains**, for diverse and numerous different user segments such as **Agriculture, Forestry, Urban monitoring, Transport, Tourism, Climate change and Environment, Blue economy, Energy & Natural resources, Disasters management, Insurance, Health, Security & Defence, Development and Cooperation**.
- This report focuses on **eight promising downstream domains / user segments ensembles – referred to here as "value chains"** in which Copernicus data and services are currently used: Agriculture, Forestry, Urban monitoring, Insurance with a particular focus on natural hazards, Ocean monitoring, Oil & Gas and Mining, Renewables energies and Air quality management.

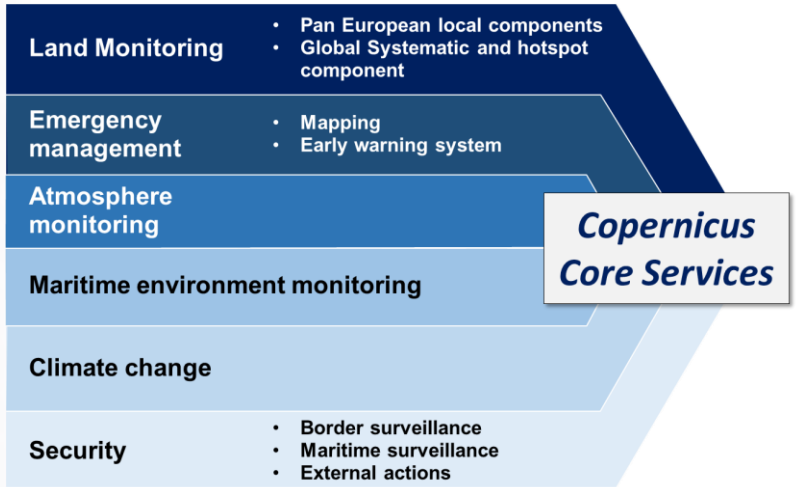
Copernicus, Europe's eyes on the Earth

What is Copernicus?

The Copernicus programme is the **European Union's Earth Observation flagship programme**. From 2014 to 2020, the European Union (EU) will commit **EUR 4.3 billion to Copernicus**.

The Copernicus programme consists of a set of components that collect data from various sources: **EO satellites (Sentinels) and a multitude of in situ sensors**. Eventually, the Copernicus programme will comprise 6 satellite categories (Sentinel 1 to Sentinel 6).

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.



Overview of the Copernicus Core Services
(Source: PwC-Strategy& analysis)

Copernicus market

Copernicus objective is twofold:

- develop an **independent EO capacity** to deliver services in the environmental and security fields;
- create **business opportunities for European companies**.

The Copernicus programme is expected to result in the creation of **about 48,000 jobs over the period 2015-2030[1].**

Copernicus is the 3rd largest data provider in the world, with 8 Petabytes per year. No previous EO initiative has ever provided such a volume and diversity of data, and this poses challenges for collection, referencing dissemination, processing and delivery.

Today, a rising number of Small and Medium Enterprises (SMEs) are focusing on the development and sales of value added services and products based on Copernicus data. According to the European Association of Remote Sensing Companies (EARSC), the sector comprises **around 400 companies in Europe, 95% of which are SMEs[4]**, and has strong potential growth prospects, with a Compound Annual Growth Rate (CAGR) higher than 10% expected over 2006 – 2014.

The global downstream market has an important growth potential and its development is of substantial importance for the EU.

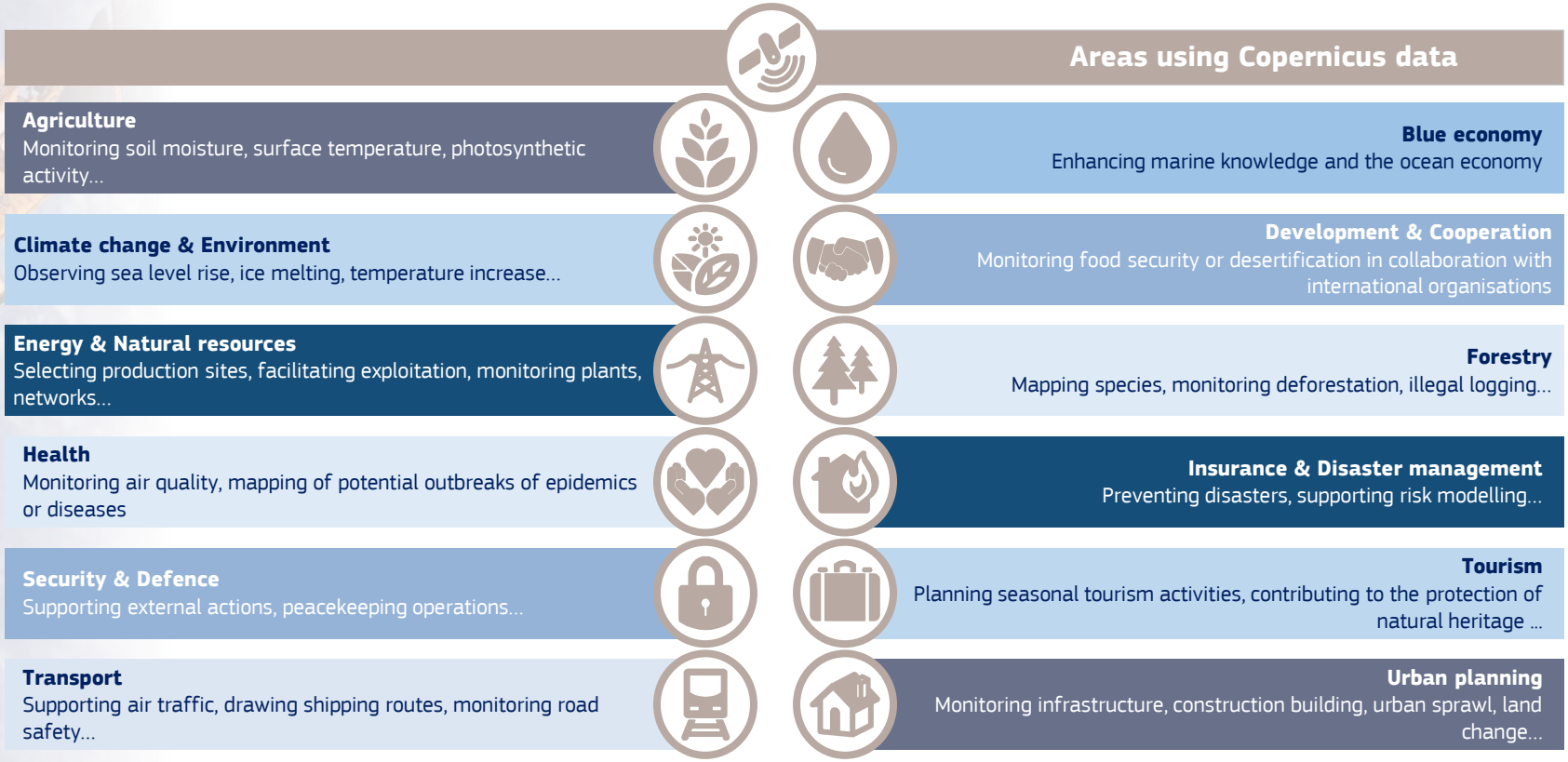
[1] *Source: European Commission, 2015, Copernicus is the EU Earth Observation and Monitoring Programme. [ONLINE]*
[2] *Source: EARSC, 2015, European Geospatial services.*

Copernicus, Europe's eyes on the Earth

Copernicus main applications areas

The Copernicus programme provides data and services that **support added value in several non-space domains**. The outputs of the programme support a **variety of applications**, potentially impacting businesses and organizations in day-to-day business and operations, and facilitating decision and policy making processes.

The present report focuses on eight promising downstream "value chains" or user segments ensembles: Agriculture, Forestry, Urban monitoring, Insurance for natural hazards, Ocean monitoring, Oil & Gas and Mining, Renewables energies and Air quality management.



Overview of major areas leveraging Copernicus data and services

AGRICULTURE

Key specificities

- Historically, **agriculture has been one of the first areas in which EO programmes have played a role**. Indeed, precision farming techniques using EO data started to emerge in the 1990s.
- The **EO downstream revenues related to Agriculture are valued at more than EUR 70 million in 2015**. Intermediate users are very heterogeneous and include a diversity of players: start-ups, micro companies, SMEs, larger players, and purely scientific players such as research organisations and universities.
- The **typology of end users is quite balanced between public players** (such as governmental authorities which need precise information in the framework of specific policies and regulations or to monitor specific issues such as food security or droughts), **and private players** (agricultural corporations, food companies, etc.).
- Farmers, which account for most of the end users for agricultural products based on EO data, may face difficulties in paying individually for the services. Thus, the direct clients of intermediate users are in many cases **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.

Copernicus applications

- Precision farming applications such as yield mapping, input management, farm management recording, etc.
- Seasonal mappings of cultivated areas
- Field scale and crop dynamics mapping
- Irrigation management and drought monitoring
- Food security monitoring and agriculture development in Africa

Copernicus economic impact (2015)

9.2 – 13.7
EUR million

Enabled revenues for intermediate users

Examples:

Improvement of irrigation management

70% reduction of the cost of a precision agriculture service, thanks to Copernicus

End user benefits

The EO market related to Agriculture

One of the first downstream EO markets

Since the1990s, EO data has supported precision farming, by contributing to the identification and quantification of ways to vary various agricultural inputs across the farm in order to tailor farming practices. These techniques allow farmers to increase their productivity by **optimising the use of water, fertilizers, seeds and pesticides**.

A rather fragmented market

A wide range of players operates in the development of VAS: start-ups and SMEs, larger players and purely scientific players. **VAS companies sometimes partner with other specialized organisations** (research institutions for example) in order to better understand the needs of end users. A few large agricultural corporations have recently acquired or are in the process of acquiring VAS companies, such as Monsanto which acquired the Climate Corporation in 2013.

Many SMEs develop value-added applications based on EO data in the agricultural sector, such as GIM (BE) which uses Sentinel-2 data to develop specific smart farming applications, or EFTAS (DE) which has developed specific products to control farms' subsidy schemes.

Launched in 2011, the **Global agricultural geo-monitoring initiative (GEOGLAM)** seeks to coordinate satellite monitoring observation systems in various parts of the world to "reinforce the international community's capacity to produce and disseminate relevant, timely and accurate forecasts of agricultural production at national, regional and global scales by using EO data".

Key Driver 1

Opportunities are expected to arise 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 which causes important droughts in several parts of the world.

Key Driver 2

The added value of EO data in the agricultural field is recognised internationally and implemented through ***wide-scale initiatives*** such as GEOGLAM, which, thanks to the promotion of remote sensing tools in the agricultural sector, is supporting the creation of potential opportunities for VAS companies.

Key Driver 3

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 in such applications.

(In EUR million)	**Overall EO downstream market [1]**	**% of the overall market for Agriculture only[1]**	**Intermediate users' revenues for Agriculture**
2012	786	7.5 %	58.95
2015	911	7.8 %	71.06

The EO market related to Agriculture

Current use of EO data in the agricultural sector

Satellite imagery can boost revenues for agricultural applications. **Applications related to EO facilitate the detection of inadequate irrigation and soil erosion**. EO outputs make a significant contribution to the efficiency of modern agricultural practice, while ensuring consistency and broad coverage of the data.

The most prominent agricultural sub-domain in which EO based products are developed is **precision farming**, for very specific techniques. The products provided are quite precise and user-friendly (some deliver comprehensive information on the state of crops using colour codes).

*Blackbridge developed **monitoring programmes for agriculture** based on a satellite imaging solution for comprehensive and regular coverage of large agricultural areas. This innovation has a huge collection capacity: it can capture more than 5 million square kms per day.*

Capture of fields near Washington in the US using the Normalized Difference Vegetation Index (NDVI)
(Source: Blackbridge, 2015)

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)	• Assessment of crop location changes • Better monitoring of food security issues
Water management and drought monitoring	Decision makers • National Public authorities • International bodies	• Prevention and improved monitoring of meteorological and hydrological droughts
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

Synthesis of current EO applications in the Agricultural sector

Agriculture-related products supporting public and private end users

Commercial and public satellite data are combined with field data

Service providers use **both data from public satellites and data from private satellites.** Service providers currently use a large amount of **Landsat** data. All the stakeholders interviewed have indicated using **Sentinel-1 & 2,** and in most cases developing precision farming applications. Service providers are planning on integrating **Sentinel-3** data in order to benefit from mid-resolution data.

Satellites from private providers are also combined with Sentinel data: **SPOT**, **Rapideye** and **Worldview** for example are used for VHR data.

Dedicated platforms are used by in-house remote sensing experts and agronomists

The **Copernicus Land Monitoring Service**, provides geo-information on land cover and variables related for instance to the water cycle.

The **Earth Observation Data Centre for Water Resources Monitoring** provides agriculture-related EO data, and a range of tools supporting collaborative processes for VAS companies.

Maps of parcels, crop masks and types developed by VAS companies

Service providers are developing a wide range of products such as **maps or images of parcels of land** which use colour codes to represent **crop disease** or a **lack of irrigation**, with information on the **amount of water or fertiliser needed for a specific portion of the land parcel** for example.

Agricultural cooperatives and public entities can then adapt their practices

Clients are typically **agricultural and industrial cooperatives** or **local relays** which then distribute the service within their network.

Public end users include **ministries and other types of governmental bodies,** and sometimes local authorities, interested in information such as seasonal maps of crops and acreages in order to assess crop location changes.

The EO value chain for Agriculture

Value-added service providers (intermediate users)

Acquiring agricultural data

Raw data

- Data from publicly funded satellites
- Data bought from private satellite operators

In situ data

- Use of different types of field data combined with EO data

Processing of agricultural data

In-house capabilities to process agricultural data

- Recruitment of experts with two types of background: remote sensing on the one hand and agronomists on the other

Use of various platforms to process the data

- Several service providers use dedicated platforms to access or process the data specifically for agriculture

Development of software and specific applications

Establishment of partnerships with other specialised organisations

- In several cases, VAS companies establish partnerships with other organisations, such as research centers specialised in one specific topic
- Partnerships with large private corporations allow SMEs to benefit from their infrastructure

End users

Used by farmers, policy makers...

Training

- VAS companies provide specific training for their clients or end users so that they can fully exploit the data and information provided

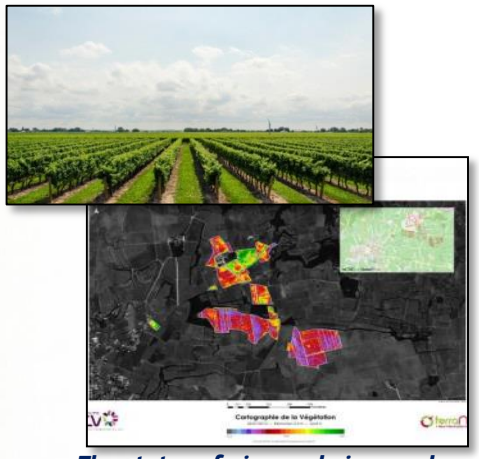
Copernicus has a substantial impact on the Agricultural sector

Sentinel data is used to develop precision farming applications

All stakeholders interviewed in the framework of this study[1] are using Copernicus data and more specifically Sentinel-1 and 2 data, in order to develop precision farming applications, for instance using Sentinel-2 data to monitor the amount of chlorophyll in plants. Sentinel-2 data is also used because of its coverage and resolution: the 10-meter resolution supports the development of field scale mapping and its 5-day revisit time capability is useful to map monthly crop dynamics. Sentinels data is also used by private stakeholders who are leading projects on food security in Africa. Some will integrate Sentinel-3 data as soon as it becomes available.

Sentinel data is **rarely the only source of data used** and is often combined EO and in-situ data. As an example, the 'crop monitor' service developed by GEOGLAM combines Sentinel-2 with Landsat data in order to obtain accurate, timely and global information on crop conditions.

*Terranis, a spin-off of Airbus geo-intelligence, has developed a specific **application for wine makers**: the objective is to optimize the wine harvest quantitatively and qualitatively. The application provides information to end users a few weeks before the harvest so that they can adjust cultivation methods to improve the quality of the wine.*



The status of vineyard vigor and heterogeneity captured by Oenoview
(Source: Terranis)

Copernicus' strengths and opportunities in the Agricultural sector

(Source: stakeholders consultation[1])

The availability and reliability of Copernicus data allows 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 for building ***networks*** and create new ***partnerships*** in the agricultural field.
The ***variety of EO products*** allows many sub-sectors to be addressed, such as precision farming techniques, water management techniques, products directed toward public authorities, etc.	The products developed based on Copernicus data are very ***functional*** and can be ***easily adapted*** to different scales and user needs.
The Copernicus programme has ***increased awareness*** among agricultural end users of the potential use of EO data , which will create new opportunities for service providers.	As economic and environmental conditions in the agricultural sector put pressure on natural resources, recourse to EO data is becoming increasingly necessary, especially in the public sector to monitor ***food security***.

[1] *Source: Stakeholder consultation based on interviews with a sample of European stakeholders from the agricultural value chain: 6 private companies of different sizes, one international organisation, one research centre and one regional network*

Copernicus significantly impacts the Agricultural sector

Economic impacts

- Use of Copernicus data in agriculture has led to **moderate job creation**
- Thanks to applications based on Sentinel data developed by VAS companies, **farmers can increase their productivity by a more efficient and appropriate use of agricultural inputs (up to 20%)**
- *Copernicus data should **create additional business opportunities** and **enable service providers to boost their sales additionally** (expected)*

Social impacts

- 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 help farmers to **produce food of better quality and which has fewer risks for human health**

*Airbus geo-information services has a leading precision farming application that was launched 15 years ago: the **FARMSTAR project.***

Approximately 15,000 farmers are using the Farmstar application. The farming cooperatives which purchase this application benefit from various solutions such as assessments and recommendation statements

*The **project Sentinel-2 for Agriculture** 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.*

Environmental impacts

- Precision farming **services reduce the potential negative impact of agriculture on the environment** by enabling a more efficient and appropriate use of inputs

Copernicus revenues in the Agriculture sector

Copernicus current enabled revenues in agriculture

As precision farming services represent about 93.3% of the revenues generated by EO services in the agricultural sector, the quantitative analysis of the Copernicus enabled revenues focuses on this specific sector.

In 2015, the European market for precision farming accounted for approximately EUR 368 million (15% of the global market) [1], of which satellite imagery technologies accounted for EUR 66.4 million. According to the stakeholder' consultation, Copernicus data represents approximately 14% of the revenues generated by intermediate users (i.e. downstream service providers) in the precision farming sector. Thus **the total Copernicus-enabled revenues for European downstream service providers operating in the precision farming sector is of the order of EUR 9 million** (conservative estimate) corresponding to 2.5% of the total revenues of the European precision market sector.

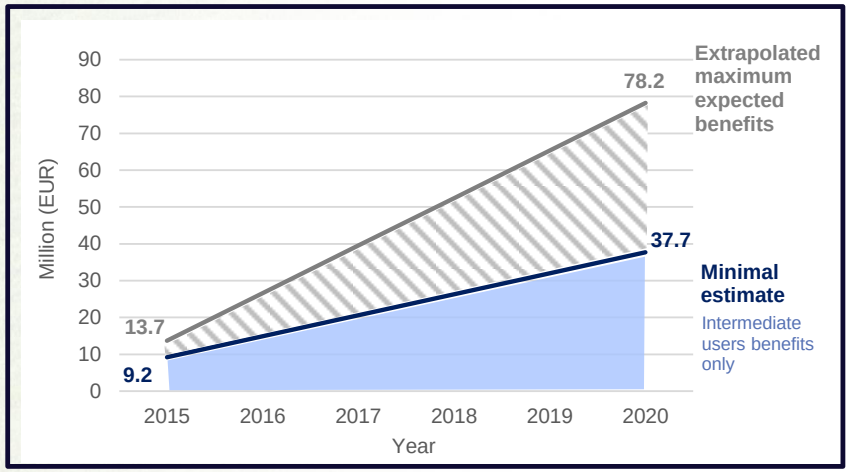
To obtain a maximum estimate, we run the same calculation using the **GIS revenue for precision farming** (instead of the EO revenue for precision farming) and obtain a maximum Copernicus-enabled revenue of EUR 13.7 million.

These estimates do not include the benefits for the end users (the farmers themselves), but only for the intermediate users (the downstream service providers).

In EUR million	Precision farming market	EO interm. users' revenues for precision farming	% of Copernicus enabled revenues	Copernicus-enabled revenues for EO interm. users for precision farming
2015	368	66.3	13.9 %	9.21
2020	641	221	17 %	37.7

In EUR million	GIS market for Agr.	GIS interm. users revenues for precision farming	% of Copernicus enabled revenues	Copernicus-enabled revenues for GIS interm. users for precision farming
2015	106	98.6	13.9 %	13.7
2020	493	460	17 %	78.2

Current and prospective revenues enabled by Copernicus in Europe for precision farming downstream service providers



Source: The report on the Copernicus downstream sector and end user benefits, prepared by PwC for the European Commission, October 2016

The projected contribution of Copernicus to global and European revenues in agriculture

The revenues enabled by Copernicus are expected to rise in the coming 5 to 10 years – both because most stakeholders are planning to integrate a larger portion of Copernicus data within the overall EO data processed, and because most applications based on Copernicus data were at only 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. Satellite imagery in the precision farming sector is forecast to **represent 34.6% of the market in 2020, of which** the revenues directly attributable to Copernicus should **reach approximately 17% of the service providers' revenues, corresponding to EUR 37.7 to 78,2 million.**

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

Case study

Improving irrigation management via EO data in Lower Austria with the help of Copernicus

Context

In Austria, due to a shortage of precipitation, the **region of Marchfeld suffers from a water resource management issue**. Farmers have begun to intensify crop production by irrigation using groundwater and **irrigation water accounts for up to 60% of the total freshwater use in this region.**

Project

The Institute of Surveying, Remote Sensing and Land Information from the University of Natural Resources and Life Sciences of Vienna conducted a demonstration campaign from May to September 2013 on an area of approximately 60,000 hectares to improve irrigation management techniques.

The particular feature of this project is that GIS and remote sensing experts decided to **target the Austrian farmers directly**, rather than agricultural cooperatives.

Stakeholders compared the irrigation volumes estimated from satellite and the irrigation supplied by the farmers in order to estimate how efficiently water is currently used.

They then proceeded to an assessment of the service with the users. The project was undertaken with the forthcoming prospect of availability of free satellite data and in particular of Sentinel-2 data (cloud-free images would be available every 10 to 15 days with Sentinel-2). The combination of Sentinel-2 and Landsat-8 data would further increase the opportunities to acquire cloud-free scenes.

Overall, the service delivered **crop development maps** available every 7 to 10 days with a spatial resolution from 10 to 20 meters, **evapotranspiration maps and information and weather data and forecasts** delivered daily and finally **specific irrigation requirements depending on crop types**.

Results

Among the 30 farmers interviewed, **50% 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**.

54% of the farmers interviewed expressed a general willingness to pay, directly, or via cost sharing, for such a service.

On the basis that a farmer irrigates up to 2 000 cubic meters per hectare per year, irrigation costs between EUR 400 and EUR 1 000 per hectare. As the entire region of Marchfeld (40,000 hectares) is irrigated, the total irrigation cost for one year would range between **EUR 8 million and 20 million**.

54 % of the farmers expressed a willingness to pay for a remote sensing service

Copernicus enabled revenues

The integration of Sentinel data in this specific irrigation management product will allow a reduction in the cost of images, which currently range between EUR 15,000 (DEIMOS-1) and EUR 35,000 (RapidEye) to cover this region.

The service based on Sentinel-2 data would have a cost of approximately EUR 1.25 per hectare per year, whereas it would range between EUR 2.5 and EUR 4.3 per hectare per year with commercial data.

70% reduction of the cost of a precision agriculture service enabled by Sentinel 2

FORESTRY

Key specificities

- In the forestry domain, **governance models vary from one country to the other**: 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 (i.e. Bulgaria, Poland Romania, Sweden), most forests are publicly managed.
- **Intermediate users of EO data** in the forestry domain include several **private players** (from micro-companies to larger players), **public research institutions, and 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)**, require participating countries to obtain highly accurate and precise data on forests and thus represent 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**, because such projects are funded by public stakeholders within limited timeframes.

Copernicus applications

- Support to perform National Forest Inventories and country-wide maps
- Measures of forest biomass (in the framework of the REDD programme more specifically)
- Monitoring of changes in forest cover (reductions due to deforestation or natural disasters for example or an increase in forest areas through afforestation)
- Monitoring of forest fires

Copernicus economic impat (2015)

4.2 – 6.2
EUR million

Examples:

Improved management of forest fires, increased wood production for forest owners…

Enabled revenues for intermediate users

End user benefits

The EO market related to Forestry

A market mainly driven by the needs of public end users

Today, more than half of the world's forests are found in five countries: Russia, Brazil, the US, Canada and China. Rapid population change and economic incentives have had very negative impacts and since 1990, around 129 million hectares of forest have been lost[1]. In 2008, **the wood-based manufacturing industry in the EU was employing about 2.8 million people, generating more than EUR 400 billion turnover[2].**

EO data can contribute to improving the management of forests worldwide by providing accurate, reliable and complete data on forests. Intermediate users include SMEs, larger companies such as Airbus geo-information, public forestry management organisations, universities or research centres. **Several publicly-funded initiatives** are also developing services based on EO data for the forestry community, such as the **Global Forest Watch (GFW)**.

Many developing countries are in need of EO data related to forestry management, especially in Africa, where 26 countries are partners in the UN's Programme on Reducing Emissions from Deforestation and Forest Degradation (REDD). The demand in Latin America, especially Brazil and Mexico, is also relatively important.

Forestry-related geoinformation services are mostly used by public end users (approximately 90%[4]). The potential market is particularly significant in countries where forestry owners are private and where VAS could thus support forestry.

(In EUR million)	Overall EO downstream market [3]	% of EO downstream market for Forestry[3]	EO downstream revenues for Forestry
2012	786	7.5 %	58.95
2015	911	7.8 %	71.06

Key Driver 1

The growing number of partner countries participating in the ***REDD programme*** will create new opportunities for service providers.

Key Driver 2

Service providers have published their ***upcoming strategy*** to better involve the forestry community in order to better define the services provided.

Key Driver 3

The launch of ***ESA's Forestry Thematic Exploitation Platform*** should raise awareness among potential forestry end users

Key Driver 4

EO data support activities such as ***National Forest Inventories***, which will encourage potential end users to make use of such applications.

[1] *Source: FAO. 2007. Private forest ownership in Europe..*
[2] *Source: Copernicus, 2013. Satellites support monitoring of Europe's green lungs. Prepared by ESA and the European Commission.*
[3] *Source: EARSC (2015). A survey into the State AND Health of the European EO Services Industry. Prepared by EARSC under assignment from ESA, September 2015.*
[4] *Source: Stakeholders consultation*

Overview of EO market related to the Forestry sector

EO applications developed for the Forestry sector

The kind of data and information made available from satellites could not be provided by field information. Firstly, 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)**. Remote sensing can allow remote areas to be covered more precisely and identify boundaries between different land-use categories.

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 and tracking in real time of forest-clearing fires and low-intensity fires.

EO data is also a highly useful tool to **monitor illegal logging of forests**. Indeed, by using high resolution data from various satellites, forest managers are able to annually monitor changes in forest coverage.

EO data is used by public and private forest managers to develop different types of **cartographies**, of forest biophysical variables for example. EO data can also be used to **monitor the impact of tree clearing within a forest by forest companies and public authorities which need to keep track of forest activities**, in order to minimise the environmental impact.

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 clearing • Optimization of forestry harvest and exploitation
Applications developed in the context of the REDD programme	• National public authorities • International organisations	• More precise and complete data in the framework of the REDD programme

Synthesis of current EO applications in the Forestry sector

The EO value chain for Forestry

Value-added service providers (intermediate users)

Acquiring forestry data

Raw data
- Data from publicly-funded satellites (such as Sentinels and Landsat data)
- Data bought from private satellite operators (such as SPOT)

In situ data
- Maps
- Field inspections

Processing forestry data

Data processing platforms
- ESA's Forestry thematic platform
- Global Forest Watch
- European Forest Data Centre (EFDC)
- Géosud

In-house capability
- Recruitment of EO experts
- Development of in-house models

Acquiring external capabilities
- Partnerships with laboratories and research departments
- Partnerships with specialised research organisations

Development of software and specific products or applications

General forestry management
- Assessment of tree stocking density
- Identification of vegetation types
- Cartography of forest vegetation
- Tracking illegal logging

Monitoring of forest degradation and deforestation
- Measurement of carbon emissions
- Pest and disease control and management: Detection of disease outbreaks

Forest fire monitoring and prevention
- Alert functions on pre-selected regions or territories

Final end users

Wide range of users

Diverse users
- Public bodies: development agencies, international organisations, governments
- Civil society
- Private companies
- Scientists

Training
- Training provided by VAS companies and research organisations to local governmental players (such as ministries)

Extract from the GFW Fires map in Indonesia *(Source: GFW website, extracted June 9th, 2016)*

Acquiring and processing data to develop specific value-added products or applications

EO data to add value to field inspections

Intermediate users use a combination of EO data and in situ data. **SPOT** offers a 1.5 meter resolution and is used for instance in central Africa (in the the REDD programme). The high coverage of **Landsat data combined with its 30 meter resolution** makes it useful for service providers covering large areas in order, for example, to produce global maps. Copernicus data adds value to the already available EO data, and almost all stakeholders interviewed use Sentinel 1 & 2 data.

Public initiatives to support the elaboration of platforms

The GFW provides maps and forestry-related information using EO for free. ESA is currently launching the Forestry Thematic Exploitation Platform for non-expert users, and the European Commission's European Forest Data Centre (EFDC) provides forestry-related information. Since 2015, the French platform Géosud has been launched by IGN and provides forestry-related data and services.

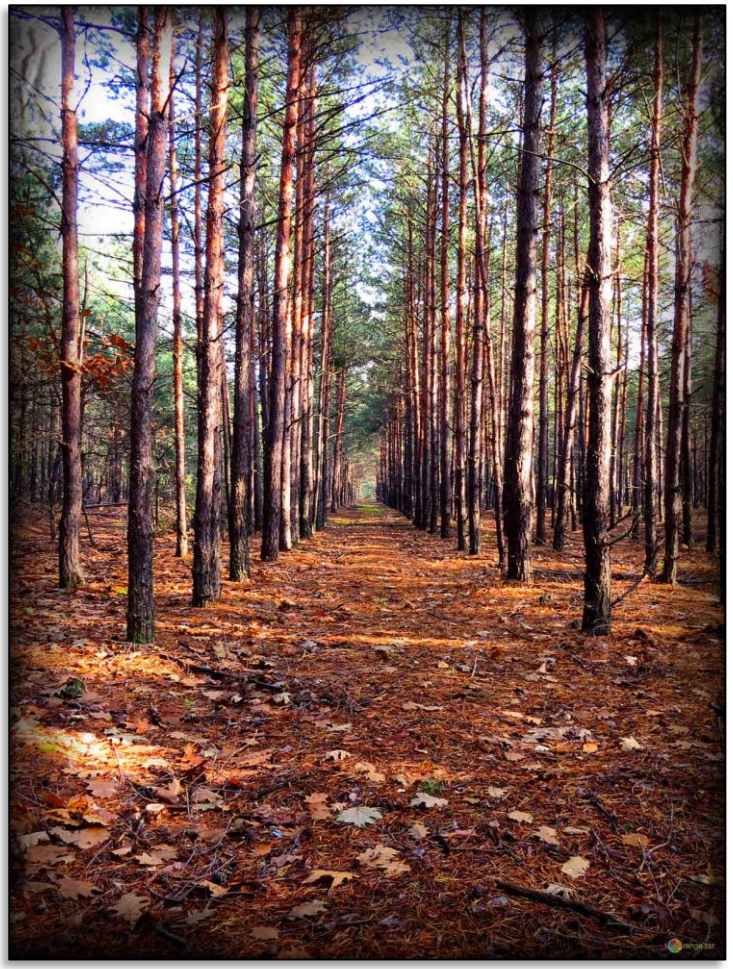
In-house development of products and software

VAS companies develop **maps or forest change products** to support forest monitoring systems. GFW users can subscribe **to specific alert functions** such as fire alerts on a pre-defined territory. In the framework of the REDD programme, GFW also provides information on the impact of deforestation on carbon emissions.

Service providers are starting to develop ever-more innovative products and **provide forestry experts** with tools that directly deliver reliable measurement. In some cases, service providers also offer **capacity-building sessions** for non-EO experts.

A majority of public end users

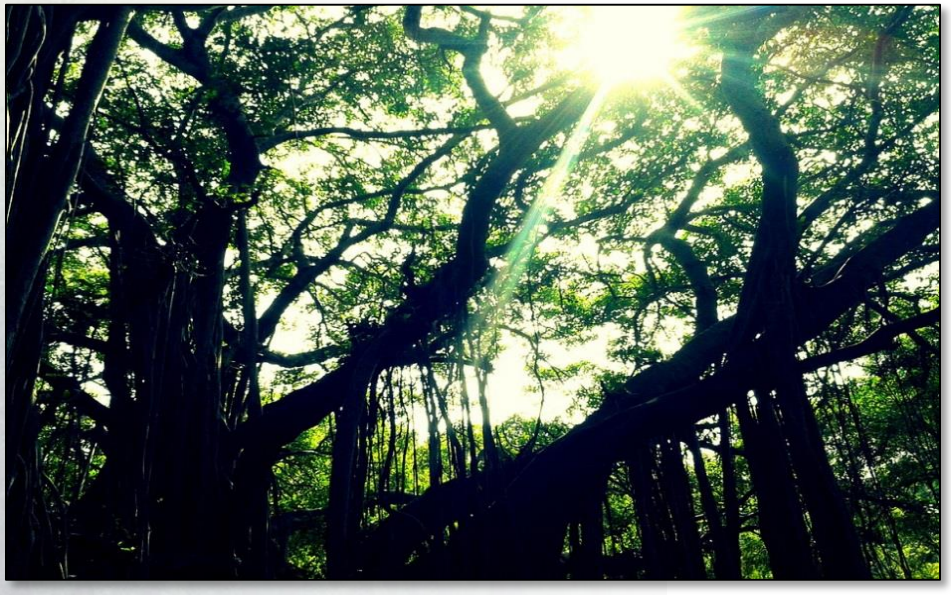
The majority of EO data end users are from the public sector: international donors (such as the World Bank), governmental and national authorities (such as ONF), national development institutions such as the German and French development agencies, NGOs and research organisations. Private end users are forest owners, private companies, forestry cooperatives or associations who manage the forest "harvest".



Copernicus data supports Forestry-related activities

Sentinel-1 & 2 data add value to general Forestry applications and more specifically to the REDD programme

Sentinel-1 and 2 data are currently already used by many intermediate users. **Sentinel 1 data** is particularly useful for monitoring vast forest regions and more specifically to detect illegal logging and deforestation. The combination of **Sentinel 1 and Sentinel 2** data will add value to global forest monitoring systems in order for example to perform National Forest Inventories and prepare country-wide maps. **Sentinel 2 data combined with SAR data** is particularly suitable for measuring forest biomass and to monitor changes in forest cover.



Copernicus' strengths and opportunities in the Forestry sector
(Source: stakeholders consultation[1])

Sentinel missions are of significant added-value for forestry because of the ***wide range of scales*** they encompass.	Copernicus provides data on most ***forestry thematic requirements***.
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.	Initiatives led by international programmes and organisations (such as GFOI) are expected to boost ***cooperation*** and raise ***awareness*** within national governments.
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 increasing need in many countries to ***systematize***, ***standardize and improve*** their forest monitoring systems creates additional opportunities for service providers.

[1] *Source: 9 major European sectoral stakeholders were interviewed: 5 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 data supports Forestry-related activities

Economic impacts

- **Sentinel data accounts for 11.5% of the total amount of EO data used by downstream service providers in the forestry value chain** (conservative estimate)
- *The **integration of Sentinel data in forestry applications should boost the use of EO by non-expert forestry** users especially through the launch of dedicated **platforms such as ESA's F-TEP** (expected)*

***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 for forests.*

Social impacts

- Copernicus data **increases the knowledge and competence of forest owners and policy-makers**
- By **better preventing and monitoring forest fires**, Sentinel data contributes to **reducing the negative impacts on public health**.

Environmental impacts

- Through the REDD programme, Sentinel data will **reduce the negative environmental impacts caused by deforestation and forest degradation**.

Copernicus revenues related to the Forestry sector

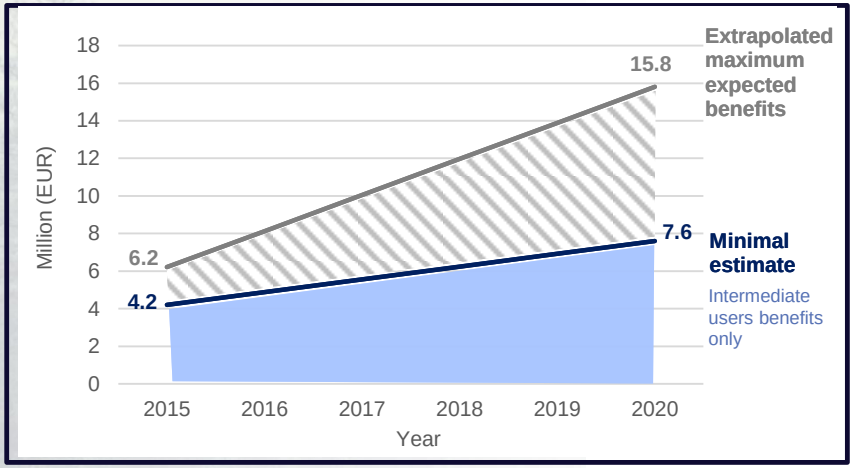
Copernicus current enabled revenues in Forestry

Based on EARSC figures [1], the EO intermediate users' revenues in the forestry domain are approximately EUR 36.5 million. Some 90% of the stakeholders interviewed are using Copernicus data and Copernicus data currently contributes approximately 11.5% of the total amount of EO data used (conservative estimate), suggesting that the value of Copernicus data to forestry management was just under EUR 4.2 million in 2015 (conservative estimate). To obtain a maximum estimate, we run the same calculation using the **GIS revenue for forestry**. This yields a Copernicus-enabled revenue of EUR 6.2 million.

This is a **conservative estimate of the value of Copernicus** because the **calculation only captures the revenue obtained by EO intermediate users**. The value of Copernicus data to end users (e.g. forest owners) may be sizeable but it is difficult to estimate based on the available information and data.

(In EUR million)	EO interm. users' revenues for Forestry	Copernicus-enabled revenues for EO interm. users	GIS interm. users' revenues for Forestry	Copernicus-enabled revenues for GIS interm. Users
2015	36.5	4.2	54.1	6.21
2020	41.10	7.6	85.5	15.8

Current and prospective revenues enabled by Copernicus in Europe for Forestry downstream service providers



Source: The report on the Copernicus downstream sector and end user benefits, prepared by PwC for the European Commission, October 2016

Copernicus' projected contribution to the global and European revenues in the Forestry sector

The impact of Copernicus for forestry-related service providers is expected to grow in the next 5 to 10 years. On the assumption of an average CAGR in EO imagery over 2015-2020 of 12.6%, the revenue generated by Copernicus would be between **EUR 7.6 and 15.8 million in 2020.** The launch of specialised platforms is expected to contribute significantly to raising awareness of end users about the benefits of EO data in their activities.

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

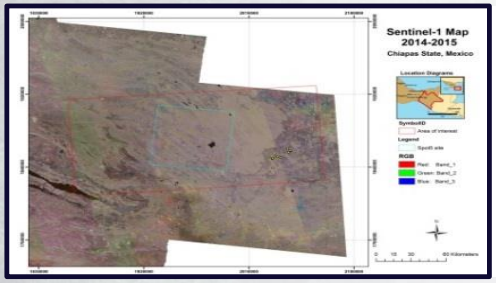
Case study

Mapping forests in Mexico in the framework of the REDD programme thanks to Copernicus

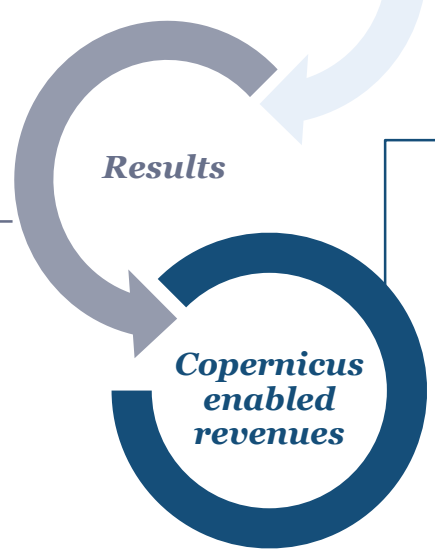
Implementation of the ESA Forestry Thematic Exploitation Platform (F-TEP) has been subcontracted to VTT Technical Research of Finland Ltd as Prime Contractor.

This dedicated platform will be a one-stop shop for both academic and commercial users, including Copernicus core services, UNREDD and other international programmes, national forest inventories, universities and research centres, forest managers, value adding industry, NGOs etc.), and will provide services based on pre-processed Copernicus and other types of satellite data, ancillary data, and computing power. The platform will provide various functionality such as access to EO data, visual product analysis, EO and GIS toolboxes, simple user interface and advanced features, support of in-situ data, product accuracy assessment, collaborative working and a support helpdesk.

All available Sentinel-1 images have been acquired and will be calibrated. A mosaic image will be developed using VTT in-house software. The forest map will be constructed by applying a random forest classifier of the Orfeo toolbox, an open source library for remote sensing images funded by the French Space Agency (CNES). The forest maps will be published with a 40 meters pixel size. Sentinel-2 data images will be selected and used if they are relatively cloud-free.



Sentinel-1 Map 2014-2015 of Chiapas Region in Mexico *(Source: VTT Technical Research of Finland Ltd and the Forestry TEP Team ESA)*



A pilot project was launched in March 2015 in Mexico in the **temperate and tropical regions of Chiapas** (73,311 km^2) **and Durango** (123,317 km^2) with the objective of using **Sentinel-1 and 2 data to map forest cover** in the framework of the REDD+ programme.

The initial phase of the pilot project consists of an accuracy assessment of the Chiapas and Durango states through randomly-sampled Pleiades data locations. In total, 100 40m x 40m "plots" of forests will be used to compose one image. Of these 100 plots, 25 will be used for model training and 75 for an independent accuracy assessment.

200,000 km²
area monitored for forest mapping

The objective of the F-TEP prime project stakeholder is for **Sentinel-2 data to account for up to 90% of the entire data processed**.

The spectral bands of Sentinel-2 missions are particularly suitable for the assessment of important structural and biochemical variables in the vegetation, and Sentinel-2 data **will improve significantly the quality of forest mappings**, **with regard to the identification of tree species for example**.

The preparation of forest maps based on Sentinel-1 and 2 data should greatly improve the efficiency of the current process which relies on field inspections only. The establishment of the Forestry TEP is also expected to diversify and balance the distribution of take-up between expert users, intermediate users and non-expert users.

URBAN MONITORING

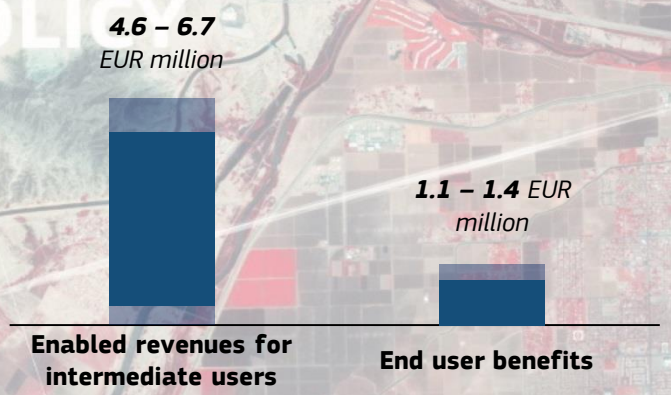
Key specificities

- EO data is already used in **many urban monitoring products** such as urban growth monitoring, land use, change detection, environmental impact management and tracking transportation routes.
- The **intermediate users are VAS companies**, mainly SMEs.
- The end users are mostly **local authorities** among whom there is increasing take-up despite some cultural barriers to the use of EO products and some budget reduction issues.
- **Some private companies** such as those operating in the construction industry or chain stores seeking to expand are increasingly buying EO-based applications.
- The **EO downstream market in urban monitoring** is already well developed, with revenues of EUR 47.4 million in 2015, representing growth of 500% 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 have also been taken up by intermediate users. Copernicus' downstream market in urban monitoring is estimated to have amounted to EUR 7.11 million in 2015.

Copernicus applications

- Urban growth monitoring
- Change detection
- 3D modelling construction
- Road and other transportation route mapping

Copernicus economic impact (2015)



Overview of the EO Urban Monitoring market

A limited market currently, but with large potential

Some 54% of the world's population was living in urban areas in 2014, a percentage that is expected to rise to 66% in 2050. Based on EARSC surveys, **the market for urban management is estimated to be of EUR 45.5 million in 2015, five times its estimated size in 2012.** This can be compared to the global smart cities market estimated at USD 312 billion in 2015 and expected to grow by 19.4% by 2020. Growth will be stimulated by the development of new smart cities EO-based applications such as 3D mappings.

The EO market for urban monitoring is fragmented as there are **numerous VAS companies providing often quite specific services.** This wide range of products typically covers topics such as: managing risk, environmental impact, managing social impact, supporting city planning activities or targeting commercial leads.

Many **local authorities are not yet aware** of the added value of EO data and **public actors and environment agencies face tight budgets** as a result of the economic crisis. Applications that particularly raise interest among local authorities are cadastres and spatial repartitions products.

New trends such as **3D mapping** are supporting sustained growth**.** Satellite data is particularly suitable for such applications as images' pixels are precisely located geographically and temporarily. In this field, even regular tasks require much customised data, generating a **growing on-demand market.**

Key Driver 1

The growth of the ***smart cities*** market and the key role that EO applications can play in this field offer strong growth prospects.

Key Driver 2

A growing number of sources of data (crowdsourced, other EO data, etc.) can be ***combined with EO data*** for urban monitoring applications and new products, such as 3D mappings or socio-economic information on the distribution of population across a territory.

(In EUR million)	**Overall EO downstream market [1]**	**% of the overall market for Urban Monitoring only[1]**	**Intermediate users' revenues for Urban Monitoring**
2012	786	1 %	7.9
2015	911	5 %	45.5

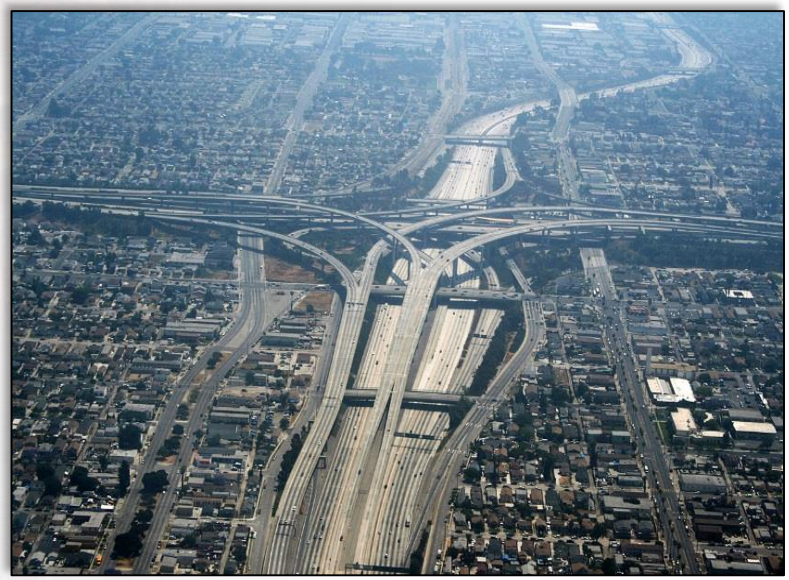
[1] *Source: EARSC (2015). A survey into the State and Health of the European EO Services Industry. Prepared by EARSC under assignment from ESA, September 2015.*

Overview of the EO Urban Monitoring market

EO data collection offers an easier and often more cost-effective method than in situ data collection and it **enables inter-country comparisons**. Another feature of EO data is its capacity for **routine periodic and unobtrusive updating**. It is also the only way to get top-down data collection, providing a **new type of information on cities**. Open source data 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 urban heat island effects. EO is also useful for producing more accurate estimates of **population size,** and for **studying the quality of life** in an area by measuring for example the temperature.

A well-known EO application is to support **land use and land cover classification.** This kind of data is used by planners for land administration issues such as site selection, resource allocation, urban growth management, slum mapping or zoning regulation. EO is cost and time effective for the **analysis of urban built-up areas** because it allows rapid mapping and detection of change as well as high-speed cadastral surveying.



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 • Citizens' welfare • Carbon sequestration
Socio-economic impact management: • Access to public services and networks • Population density	• Local authorities • Research centres • Private actors for commercial purposes	• Countering exclusion • Providing the right public services at the right place • Understanding city dynamics
City planning: • Mappings • Routes for transport • Urban sprawl management	• Local authorities • Transport operators • Research centres	• Creating scenarios to optimise infrastructure investment and exploitation • Prevention and mitigation of uncontrolled urban sprawl
Market research: • Detection and analysis of construction sites • Identification of sites for new stores management	• Private actors related to the construction industry • Major chain stores	• Advantage over competitors • Time and cost savings for market research

Synthesis of current EO applications in the Urban Monitoring sector

Urban Monitoring data flow along the value chain

Value-added service providers (intermediate users) | **Final end users**

Acquiring geoinformation

EO Data
- Copernicus (Sentinel 1, 2, 3, 5)
- Landsat
- Terra (MODIS, ASTER)
- Private satellites (TerraSAR-X, RapidEye, Worldview, etc.)
- Historical data

In situ data
- Air quality
- Temperature
- Etc.

Statistical data
- Public population statistics
- Big data

Processing geoinformation

Data processing platforms
- Urban Atlas, ESA Urban TEP, Corine Land Cover, PEPS, etc.

Processing
- Combination of EO data, in situ data and sometimes statistical data.
- Historical data can also be used (e.g. for change detection)

In-house capability
- Skills in Geoinformation systems and spatial technologies

Development of software and specific products or applications

Urban sprawl monitoring
- Share of urbanised land (%)
- Consumption of prime agricultural land for urban uses
- Per capita availability of open spaces
- Urban density
- Integration of new urban development in the public transport network

Slum mapping
- City mappings that identify slums

Land administration / cadastral
- Land detection; 3D imaging, mapping

Climate and well-being
- Soil sealing
- Vegetation indices

Use by end users

Access to urban monitoring products based on EO
- Platforms for delivering products to users (company's own platform, shared platform)

Use of EO products in urban monitoring activities
- Support to decision making in local authorities, governments, NGOs, international organisations, and private actors

Urban Monitoring data flow along the value chain

Complementary data are used

For **mapping applications,** low and medium resolution satellite data is often used as a starting point before being combined with in situ or VHR satellite data. These images can come from **SPOT 5, Landsat, DMC3, Sentinel-2**. **Urban Atlas** and **CORINE Land Cover**. SAR data is mainly used for change detection, and comes from **TerraSar-X, RADARSAT, COSMO-SkyMed, TanDEM-X, Sentinel-1**. Historical data for comparion to detect change over time typically come from **ERS, ENVISAT**.

Accessing data through a range of platforms

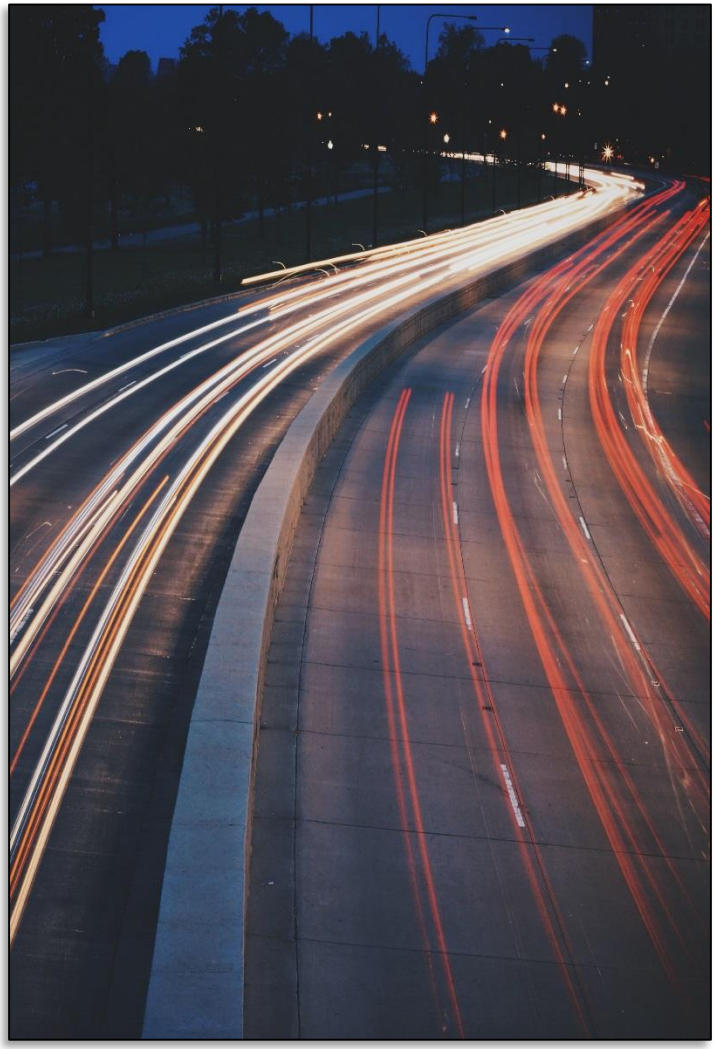
The **Copernicus Land Monitoring Service** provides several products useful for urban monitoring, such as the CORINE Land Cover and Urban Atlas. Other platforms such as **PEPS, ESRI, EODC, Amazon S3 or API** are also used by industry players. **CloudEO**, in particular, helps users identify relevant data and discover new products.

A large variety of products

EO data can be uploaded in a **GIS to analyse urban surface temperatures or land cover** and to find the nature of the correlation between different variables. Change detection has different applications such as monitoring urban growth, determining the best route for a metro line or verifying the stability of a structure. Some VAS providers produce urban mappings, construction sites mapping and single building mapping to map with high precision the population density.

A majority of public end users

The clients willing to pay for data come mostly from **local authorities**. Other public users are **national governments**, **NGOs**, and **international organisations**. However, an increasing number of private actors buy EO products, such as transport and construction companies, energy & utilities companies and real estate agencies.

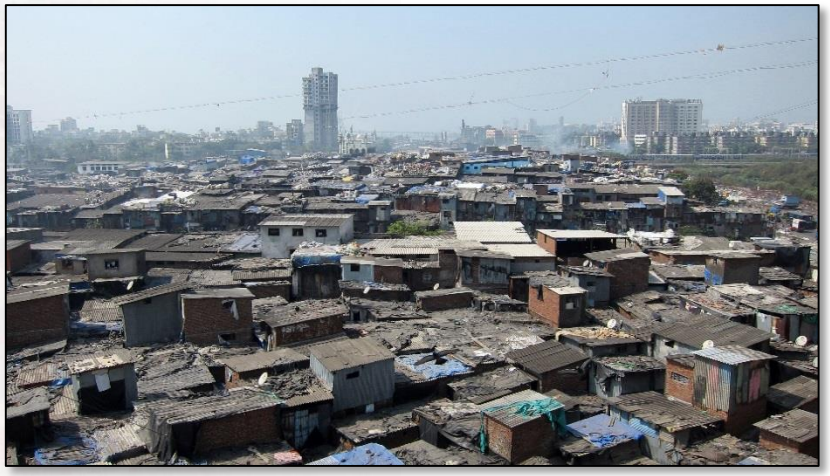


Copernicus data supports Urban Monitoring-related activities

Sentinel-1 and 2 data have multiple uses

Sentinel-1A radar data is used for change detection and the development of 3D models. It provides all-weather imagery with a rapid revisit period (6 days), with a wide area coverage and a millimeter accuracy. Sentinel-1 data can also be used for road and other transportation route mapping. **Sentinel-2 data** provides relevant data for urban growth monitoring thanks to its high spatial resolution optical imagery. The **Copernicus Land Monitoring Service (CLMS)** supports urban planning applications with products such as the **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.



Copernicus' strengths and opportunities in Urban Monitoring

(Source: stakeholders consultation[1])

The ***quality*** of Copernicus data supports many applications for cities	Sentinel-1A is the first satellite designed to disseminate ***radar images*** covering large areas and enabling temporal comparison
SMEs developing urban products benefit from R&D partnerships with other SMEs abroad	***UAVs data*** will improve in the future, creating more opportunities of applications based on both Copernicus and UAVs data
The emergence of advanced algorithms to extract data from satellite imagery, or greater ***computational power*** open new opportunities for urban remote sensing applications	Copernicus enables the creation of ***partnerships*** which organise the supply for local authorities (e.g. SparkInData)
EO is often the ***best available source*** of data for urban monitoring in developing countries	

[1] *Source: Stakeholder consultation based on interviews with a sample of European stakeholders from the urban monitoring sector: 18 stakeholders including 12 VAS companies, 4 public actors, 1 non-profit association and 1 research centre.*

Copernicus data supports Urban Monitoring-related activities

Economic impacts

- Sentinel-1A enables the **development of new products** in urban monitoring (e.g. to monitor construction sites)
- Sentinel-2 allows VAS companies to **save time and money** by focusing the use of expensive VHR data only where it is required
- VAS companies estimate that at least 15% of their revenues in EO urban monitoring is directly attributable to Copernicus
- The Copernicus programme has a **strong network effect**, encouraging partnerships between VAS companies to coordinate their efforts. Some compnies expect a **10% of growth** from such initiatives and Copernicus helps them **finding funding sources.**
- *Sentinel-3 will **improve accuracy of existing products and enable the creation of new products** (expected)*

Social impacts

- Copernicus contributes to **the maintenance of a good quality of life and access to public services**
- Copernicus **increases companies' competences (by up to 80%** for companies interviewed within this study)
- *Sentinel-3 will enable the **monitoring of regional areas** (expected)*

Environmental impacts

- Copernicus helps **forecasting and prevention of Urban Heat Islands**,
- *Sentinel-3 will help planners to make cities **more energy-efficient** (expected)*
- *The Copernicus Climate Change Service (C3S) will improve the management of the environmental impact of cities (expected)*

Strategic impacts

- Having competences in using Copernicus is a **competitive advantage** for VAS companies

*Based on the cost-effective multi-scale approach using Copernicus, the VAS company GIM managed to **map all slums in the city of Manila in the Philippines** in order to estimate the density of the population. They achieved a particularly high level of precision allowing all slums to be identified and classified: **27% of the detected slums were pocket slums** that had never previously been identified.*

Copernicus revenues related to Urban Monitoring

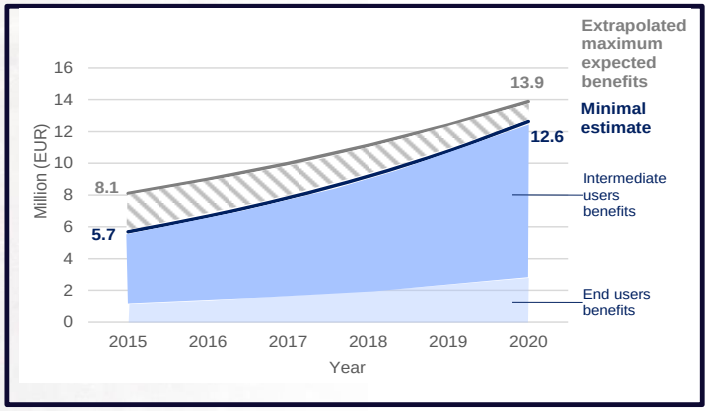
Copernicus' current enabled revenues in urban monitoring

The revenues of EO intermediate users' (i.e. downstream service providers) attributable to urban monitoring are estimated to have amounted to some EUR 45.5 million in 2015[1]. According to the stakeholders interviewed, Copernicus generates minimum 10% of their revenues, leading to a conservative estimate of the **Copernicus-enabled revenues of EUR 4.6 million in 2015 for downstream providers**. To obtain a maximum estimate, we run the same calculations with the GIS market for urban monitoring and obtain a EUR 6.7 million Copernicus-enabled revenue. In addition, we follow a study from CISCO[2] which estimates that investment in Smart cities produces a 25% return on investment. Under such assumption, the benefits for end users (i.e. the municipalities) would represent between EUR 1.1 and 1.4 million.

Copernicus' projected contribution to global and European revenues in urban monitoring

The EO market for Urban Monitoring is expected to grow by 17% every year from 2015 to 2020. Assuming a constant share of Copernicus-enabled revenue (10%), a conservative estimate of the **expected value of Copernicus data by 2020 is around EUR 12.6 million**. This includes EUR 9.9 million for intermediate users and EUR 2.5 million of end user benefits. However, Copernicus data will likely grow in importance., notably with the operations of **Sentinel-3** is expected to provide land-surface temperature.

Current and prospective revenues enabled by Copernicus in Europe for Urban Monitoring (intermediate/downstream and end users)



Source: The report on the Copernicus downstream sector and end user benefits, prepared by PwC for the European Commission, October 2016

(In EUR million)	EO interm. users' revenues for UM	Copernicus-enabled revenues for EO interm. users	GIS interm. users' revenues for UM	Copernicus-enabled revenues for GIS interm. users
2015	45.5	4.6	66.9	6.7
2020	98.7	9.9	104.4	10.4

(In EUR million)	Conservative estimate of Copernicus benefits for end users	Optimistic estimate of Copernicus benefits for end users
2015	1.1	1.4
2020	2.5	2.6

An **increase of the number of urban monitoring users** is forecast in the coming years. **Copernicus Climate Change Service (C3S) will soon disseminate products dedicated to cities** that will enable planners to monitor the environmental impact of cities, increasing the number of users of EO data for sustainable development purposes. Sentinel-3 and Sentinel-5B data will also be key to the development of environmental applications.

[1] *EARSC (2015). A survey into the State and Health of the European EO Services Industry. Prepared by EARSC under assignment from ESA, September 2015.*
[2] *Cisco, 2014. Smart and connected communities. Solutions for a Smart city. EMEA.*

Case study

Copernicus for early detection and remote monitoring of construction sites with Building Radar

Building Radar is a German start-up which **supplies verified construction sales leads worldwide,** providing information such as a construction site location, the construction phase, the building size and other data on construction projects. The clients are buildings-related companies. One of the applications developed by Building Radar gives construction companies an **immediate overview of progress of work** and helps them to identify potential issues in advance.

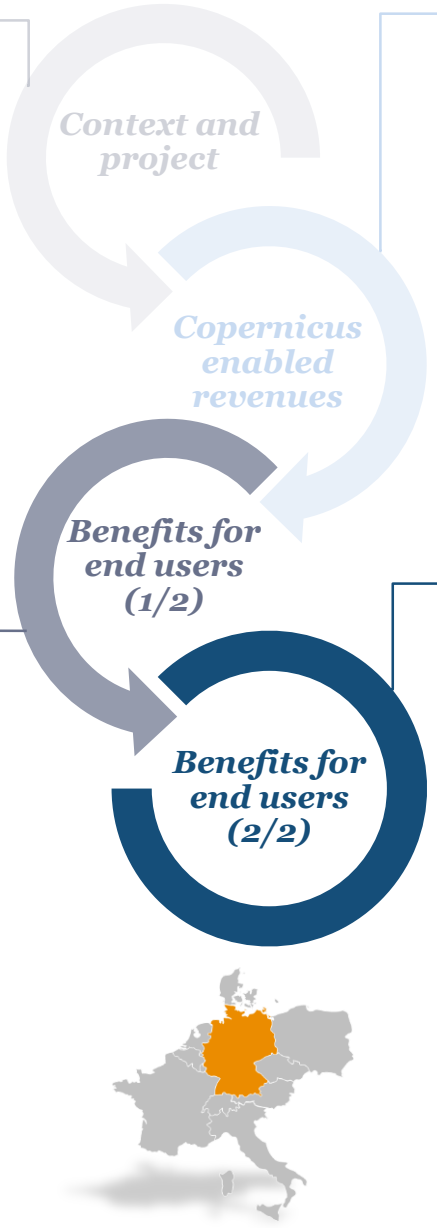
Building Radar relies on EO data, **in particular Copernicus**, and Internet data processed through their algorithms.

Building Radar estimates the **world market for sales leads in the construction sector at more than EUR 70 billion**.

Building Radar won the Copernicus Masters Grand Prize in 2015.

Building Radar enabled its clients to **gain time, increase their turnover and their sales performance**. On average, **Building radar enables its users to save 3 hours per day and €60K per year**. Following are selected examples of Building Radar's clients' success stories.

Stanko Team is a flooring supplier. Traditionally, they hired consultants or relied on paper directories to get leads for construction projects but this proved to **be five times more expensive than Building Radar's solution**. Building Radar has provided them with several thousand current, new, completed and proposed projects in their market at a competitive rate. Building Radar's satellite technology based on Copernicus, also helped them **to save 8 hours of driving and viewing per project**.



Building Radar's business model directly depends on Copernicus (**60 % of the satellite data they use)** as they could not have afforded fee-based data.

40% of their clients use applications which rely on Copernicus data; the other 60% rely solely on Internet data processing. Given their monthly turnover is between EUR 10 to 50K, it can be estimated that **EUR 4K to 20K** is directly attributable to Copernicus. Building Radar is planning for **a turnover growth rate of 30%.** The share of turnover directly attributable to Copernicus is expected to increase in the future with the release of Sentinel-2B data and the possible use of Sentinel-1.

EUR 4 to 20K, with 30% monthly growth
monthly turnover directly attributable to Copernicus

Gerhardt Braun is a medium-sized enterprise in the construction sector. 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; their research projects are finished on average **30% faster**.

Fundoland is a company based in China operating in the amusement industry. Building Radar provides them with construction projects in over 100 countries, allowing them to save **50% of their time**, and 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 and their **sales have grown by 30%**. It enabled them to automate their lead generation process and to reach **150% more leads every day**.

INSURANCE

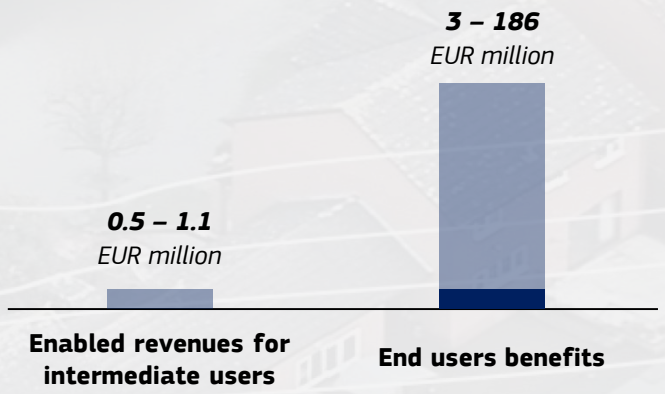
Key specificities

- The insurance and reinsurance applications benefiting from EO include different types of insurance policies, covering **natural hazards, crops insurance and livestock insurance**.
- Traditional (re)insurance activities such as risk modelling and loss assessment exploit EO as a **complementary source of data**, which is not critical and which offers a moderate added value.
- **EO is the enabler for the more recent development of index products**, particularly adapted for crops and livestock insurance. These products are relatively young (less than 20 years), and although still a relatively minor activity, they are expected to continue growing in the coming years.
- EO exploitation reveals opportunities for **costs reductions** on existing insurance policies and processes, as well as the development of **new addressable markets** especially in emerging countries and remote areas.
- **Strong variations exist in the maturity of the use of EO** between (re)insurance companies. Though exceptions exist, reinsurers and large insurers tend to be pioneers in the EO exploitation.
- (Re)insurers are **not EO experts** but have **very specific needs** for some applications, especially on index products. Ensuring these needs meet with external EO expertise is a critical aspect.

Copernicus applications

- Tracking and forecasting of storms, cyclones and hurricanes, and their routes
- Tracking of potential floods to send early warnings
- Identification and delineation maps of damaged areas after natural disasters (floods, earthquakes, fires)
- In case of large fires, identification of initial and potential new fire departures
- Computation of indexes for parametric products for crops and livestock insurance (expected in coming years)

Copernicus economic impact (2015)



Overview of EO market related to Insurance and Reinsurance

A traditional market with moderate yet various benefits from EO

The insurance sector benefits from EO applications for natural disasters hazards. The extent of events can vary substantially from one year to another, and on average over the past 10 years the insured losses in Europe amounted to about **EUR 6.2 billion per year**, representing about half of the overall losses due to natural disasters.

The traditional claim-based insurance schemes benefit from **costs savings methods and processes in the loss assessment phase**. Satellite images can also improve the **level of customer service** in the early warning phase and the claims processing phase.

Different sources of information are exploited by (re)insurers to gather data on natural disasters (meteorological, seismologic and atmospheric agencies), and **satellites images stand as a complementary source**. The added value of EO data itself remains hard to isolate and **(re)insurers are sensitive to the acquisition cost of these images**. In this context an **open data policy**, such as for Copernicus, is an important aspect.

More innovative schemes, **fully enabled by EO data** and developed since the late 1990s for **parametric insurance**, opened **new market opportunities,** especially in emerging countries, by circumventing the prohibitive cost of traditional approaches.

(Re)insurers combine specific needs to customise EO raw data and a general **lack of expertise,** and they often rely on external experts such as VAS companies. However a **gap still exists between the need for insurance tailored products and the VAS companies products.**

Key Driver 1

Potential for ***costs savings*** approaches and improvements of the level of ***customer service*** for loss assessment processes.

Key Driver 2

EO opens opportunities for ***new (re)insurance policies*** with high applications potential in ***developing countries***, increasing the customer base.

Key Driver 3

Open data policy and global coverage of satellites foster the adoption of EO products in a context of limited added value over other existing data sources.

Overview of EO market related to Insurance and Reinsurance

Current use of EO data in the (Re)insurance sector

Risk modelling consists of a probabilistic approach to the likelihood of a natural catastrophe, anticipating the amount of indemnities to be paid and therefore pricing the premiums. EO, as a complementary source to traditional sources is not perceived as critical by (re)insurers. **Strong discrepancies are witnessed in the EO practices** between (re)insurers, as some of them do not exploit EO while satellite images represent up to 70% of the input data for others.

Loss assessment consists in defining the amount of indemnities to be paid by reconciliating the claims from the clients and the actual material damages undergone. EO contributes to anticipating the event by allowing companies to **warn the clients and to reduce the material damages**, **adjust the sizing of their teams and mobilise field experts**, improving the customer service. After the events, satellite images provide a global picture of the scene, **optimising the intervention of experts** and reducing the associated costs.

Index products are enabled by satellite images, and are based on the regular monitoring of **natural parameters** such as the **vegetation biomass**. Indemnities are paid when the biomass is estimated to have fallen below a defined threshold and the challenge is to ensure the correlation between the index and the reality is robust. This task is achieved by 3rd parties with EO expertise such as VAS companies or universities.

	Applications	End users	Benefits
Risks modelling	• Update of risks models with EO data • Validation and calibration	• Reinsurers • Insurers • Catastrophe modelling companies	• Higher accuracy of models • Better control of financial risk
Loss assessment	• Anticipation of catastrophe • Observation of affected area	• Reinsurers • Insurers • Insured people • Emergency services	• Early warning, reduction of damages • Better sizing of call centres and experts • Optimised intervention schemes
Index products	• Computation of indexes	• Reinsurers • Insurers • Farmers	• New markets in remote areas • Access to insurance products for new populations

Synthesis of current EO applications in the (Re)insurance sector

The parameters for the Insurance sector along the EO value chain

Value-added service providers (intermediate users)

Final end users

Acquiring Insurance EO data

Raw data
- Open data (Landsat, Sentinel, Terra / Aqua) for low and medium resolution data
- Paying data for rapid acquisition on specific locations
- Need for customisable data

Pre-Processed data
- Shared between insurers and reinsurers

Processing EO data

Data processing platforms
- Fees to access platforms for data manipulation

In-house capabilities
- Only within large structures
- Few people dedicated to EO data processing in insurance companies
- Storage of historical data to build long term database (>10 years)

Outsourced processing
- Computation of indexes by EO experts

Development of software and specific products or applications

Risks models for forecasts
- Risks modelling performed internally
- Outsourced risks models

Loss assessment
- Impact sizing prior to event
- Event footprint after the event

Parametric products
- Biomass index for crop and livestock insurance

Seasonal monitoring
- Continuous health monitoring for crops

Benefits of EO for end users

- **Improved level of customer** service
- **Supports fraud detection**
- Ability to insure **remote populations**
- Improved intervention schemes for **emergency services**
- Increased knowledge basis for **scientific community**

The parameters for the Insurance sector along the EO value chain

There are a wide variety of satellite sources, dominated by Landsat and MODIS

As of 2016, index products are mostly built on data from **Landsat and Terra / Aqua satellites**. Landsat 8 offers a good resolution at 30 meters per pixel while MODIS data offers a high revisit frequency of 1 to 2 days. The Sentinels capabilities (resolution, revisit frequency, radar instrument) are well adapted, but they face a lack of data history with just 1 year available.

Risk modelling involves similar sources of images, but other commercial sources are used such as the **Worldview** and **Quickbird** satellites of DigitalGlobe.. In the case of loss assessment, commercial satellites manoeuvrability and high revisit frequency are assets. Furthermore damages assessment by EO is more relevant with higher resolution images. SPOT and Pléiades (Airbus Defence & Space) are common sources for such applications. Insurers acquire raw data using both the image providers' platforms and cross sources platforms such as the S3 platform of Amazon Web Services for instance.

Insurance EO products answer to specific needs

EO data allows risk models to be validated and calibrated. This service can be performed internally but can also be provided by reinsurers to their clients (insurers). Typical products for loss assessment include **delineation maps after floods, vulnerability maps for landslides and coastal erosion, or analysis of burnt areas** (fire departures, propagation, and new potential starts). Index EO products consist in a mapping of the biomass indexes. EO experts are necessary to produce these indexes.

Users benefits go beyond insurance sector

Individuals and businesses benefit from **reduced losses and quicker handling of their claims**. **Farmers** in developing countries with hostile weather conditions can have access to insurance coverage thanks to EO data. EO also benefits public-sector organisations for **civil protection** teams and **emergency services**, and supports **scientific research on** climate change and natural disasters.

Copernicus contributes to various aspects of the Insurance business

Copernicus contributes to different products and practices of (re)insurers

The data provided by Copernicus is complementary to other satellites and non satellites sources. The improvement of risks models relies on **post event learning**, by comparing the model forecasts and the actual events. This **validation and calibration activity** leads to more reliable models. The images also enable the assessment of the **vulnerability** of the territories (coastal erosion, past floods and fires footprints, landslides etc.).

Sentinels images can be used for **event anticipation**, to monitor the routes of storms, and for post event treatment, to **assess the extent of the damages** and create delineation maps. It helps to optimise **commissioning of resources and expertise**.

Copernicus strengths and opportunities in the (Re)insurance sector

(Source: stakeholders consultation[1])

Sentinels data are ***reliable and trusted***, their technical capabilities allow monitoring large areas with good resolution and revisit frequency	Sentinels data offers ***SAR*** [2] capabilities over similar sources of data (Landsat, Terra/Aqua)
Sentinels data have an easily ***customisable*** format for non-EO experts	Catastrophe modelling is perceived to still not be exploited at its ***real potential*** for crop and forestry insurance
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
Sentinels technical capabilities (swath, resolution, revisit frequency) are well adapted to ***index products***	***Artificial reconstruction*** of data history could accelerate the rate of adoption of Sentinels' data

[1] *Source: Stakeholder consultation based on interviews with a sample of stakeholders from the Insurance sector: 17 stakeholders among which insurers, re-insurers, VAS companies*

[2] *Small Aperture Radar, by opposition to optical capabilities*

Copernicus contributes to various aspects of the (re)Insurance business

Economic impacts

- **Lower financial risk** through more accurate risks modelling. The current impact of Copernicus is moderate but an increase can be expected in the future.
- **Costs reductions** through catastrophe anticipation (but the impact of Copernicus is still limited).
- Copernicus is forecasted to generate additional revenues from index products in the future.

Social impacts

- Access by **remote and precarious populations** to insurance products to support their agricultural activities against risks related to natural disasters.
- Improved **quality of service to insured people**: early warning for preparation and improved response delay after the event.

Environmental impacts

- Statistical and reliable data about natural disasters events, for **scientific knowledge** and **political awareness**, to help better prevent future events.

Strategic impacts

- **Improved interventions schemes** for emergency services and civil protection through large scale, dual optic/radar, reliable data for natural catastrophes mapping.

Copernicus revenues related to Insurance sector

Copernicus enabled revenues in the Insurance sector in 2015

As of 2016, the economic benefits of Copernicus for intermediate users in the Insurance sector (EO/GIS companies) remain limited, between EUR 0.5 and 1.1 Million, due to both its limited use as a data source and the moderate added value of EO in general over other data sources. However, **the Copernicus-enabled revenue for downstream service providers in the insurance market is expected to grow at 64% per annum until 2020, up to EUR 13.6 million.**

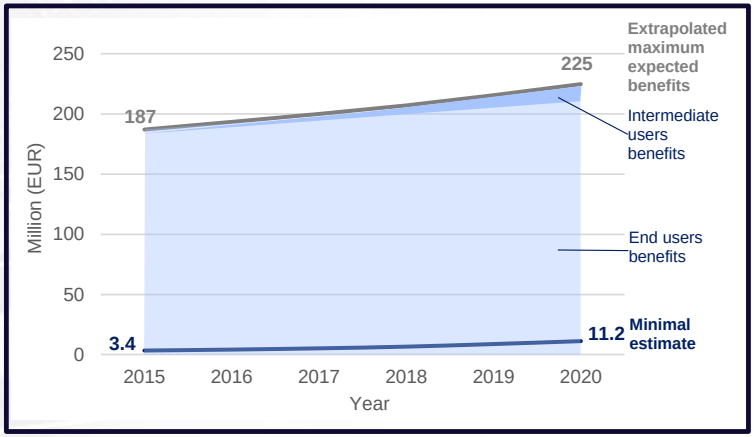
In addition, **the benefits for end users (the insurance companies) could be as high as EUR 186 million.** Indeed, even if the penetration of Copernicus is still relatively limited, the insurance market is substantial, leading to a large impact of Copernicus. The quantification of economic impacts from Copernicus for Insurance end users remains a delicate exercise, which explains the large confidence intervals. Indeed, the activities of catastrophe modelling do not represent sources of revenues but rather costs for (re)insurers, it is still too early to discern clearly the impact of Copernicus, the contribution of EO itself is hard to distinguish from the other sources of information, and strong discrepancies exist within the (re)insurance sector regarding the practices on EO.

In EUR million	Total EO interm. users' revenues for insurance[1]	Copernicus enabled revenues for EO interm. users	Total GIS interm. users' revenues for insurance	Copernicus enabled revenues for GIS interm. users
2015	35.4	0.5	74.9	1.1
2020	79.5	8	135.7	13.6

(in EUR million)	Insured losses in Europe*	Enabled revenues for end users ((re)insurers)
2015	6200	2.9 – 186
2020	7039	3.3 – 211

** Average on 10 years*

Current and prospective revenues enabled by Copernicus in Europe for the (Re)insurance market (intermediate/downstream and end users)



Source: The report on the Copernicus downstream sector and end user benefits, prepared by PwC for the European Commission, October 2016

Some insurance applications linked to losses assessment require specific satellite capabilities which are not in the scope of Copernicus (high resolution, steerable satellites for instance), therefore with no forecasted evolution. Index products do not yet 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, implying a **progressive increase in the use of Copernicus**. From an economic perspective, the principle of parametric insurance is more attractive than the traditional business model (automated process), and (re)insurers have many reasons to support its development. However it can be noted that the insurance parametric products account for a very small share of insurance revenues in Europe (below 5% seems a realistic assumption).

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

Case study

EO-based NDVI agricultural insurance product for the Spanish market by Agroseguro

Context

The *Agrupación Española de Entidades Aseguradoras de los Seguros Agrarios Combinados S.A.* (**AGROSEGURO**) is in charge of managing the agricultural insurance on the Spanish market on behalf of the shareholding insurance companies, insuring productions such as crops, livestock, aquaculture and forestry.

Previously the animal breeder was not covered against damage caused by the lack of pastures. **Insurance against lack of pastures was developed** in 2001, based on the **NDVI (Normalized Difference Vegetation Index)**. This index measures the quantity and lushness of vegetation. The indemnity is calculated based on the extra cost for feeding animals when there is not enough pastures due to a climatic event (usually drought).

Project

A **map of land uses for pastures was established and divided into homogeneous areas, based on CORINE Land Cove.** During 2001-2009, **NOAA satellite** images were used to set the index, and since 2010 images changed to **Terra & Aqua satellites**, as they had accumulated a sufficient historical record and could provide a better pixel resolution. Currently, the satellites make a **daily pass through the Iberian Peninsula**, and **each pixel has a size of 6.25 hectares (250 m x 250 m).** The vegetation index is calculated **every ten-days period** by the Remote Sensing Laboratory of the University of Valladolid. A pay out occurs when the vegetation index is lower than the guaranteed vegetation index during **at least 3 ten-days periods**.

10 days	**250 m**
Index update	Pixel size

Results

The number of insurance policies jumped from 63 in 2001 up to between 4,000 and 5,000 each year since 2004, and totalling around EUR 11.5 million of premiums in 2015. This product as led to a **reduction of the insured producers input costs (mainly due to drought).** In 2005 more that EUR 65 million were paid to producers and in 2012 indemnities to producers amounted to more than EUR 40 million. Over the 2001-2015 period, the 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.

4200	**EUR 167 M**	**60,000**
insured	Pay-outs	claims

Copernicus enabled revenues

Based on Spanish market size and the share of meadows and pastures in Spain with regards to Europe, a **broad estimate of the potential market value for livestock index insurance in Europe can be evaluated around EUR 516 million**.

Copernicus can provide the NDVI index through Sentinel 2A (spectral bands 4 and 8), but there remains uncertainty on the final market penetration of the Sentinels. On the assumption of a share of Sentinels of about 1/3 of the total by 2025, the Copernicus enabled revenues for the European index products market can be estimated around EUR **172 million**.

EUR 172 M
Projected enabled revenues by Copernicus

OCEAN MONITORING

Key specificities

- The ocean monitoring sector comprises **many 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, commerce and trade.
- **Intermediate users** are private companies of various sizes (from micro-companies to large companies), public authorities, research centres or laboratories.
- **End users** are both from the public (ministries, local governments, laboratories, sea authority centres) and private sectors (fish farmers, farming cooperatives, etc.).
- The ocean environment is characterized **by rapidly changing parameters** (for example, changes related to weather conditions), requiring very precise data – such as near-real time data – which makes EO data an important source of information.
- EO revenues for the ocean monitoring sector amounted to **EUR 103.85 million in 2015** among which **EUR 5.76 million** can be directly attributable to Copernicus.
- The **Copernicus Marine Environment Monitoring Service (CMEMS)** already counts more than 5,000 users, 80% from which emanate from the public sector.
- The ocean monitoring sector will be the primary sector impacted by **Sentinel-3 data**.

Copernicus applications

- Measure water quality, detection of micro bacteria, roughness features
- Monitoring of harmful algal blooms
- Mapping of fishing zones
- Mapping of Marine Protected Areas
- Monitoring of coastal erosion

Copernicus economic impact (2015)

5.8 – 8.6
EUR million

Example: the ASIMUTH project for the European Atlantic coasts enabled a **EUR 2.3 million** loss reduction per year

Enabled revenues for intermediate users

End users benefits

Overview of the EO market related to Ocean Monitoring activities

A diverse market for ocean-related products

With each European citizen consuming around 20kg of fish products per year, **fish is one of the world's most important sources of food**. The total contribution of ocean exploitation to the global economy is challenging to assess, because coastal and ocean economies are sometimes blurred. In Europe, fishing and fish processing employs more than 350,000 people.

Ocean monitoring-related issues account for one of the most important sectors in terms of revenues within the European EO market. However, the recent EARSC industry survey seems to indicate that revenues generated by ocean monitoring-related EO products decreased by approximately 20% between 2012 and 2015.

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.

Out of these companies, the two sub-sectors in which most companies are active are **marine ecosystems** (accounting for 46%) and companies operating in the field of the **coastal sub-sector** (accounting for 36%).

Regarding the market structure, **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).

(In EUR million)	**Overall EO downstream market [1]**	**% of the overall market for Ocean Monitoring[1]**	**Intermediate users' revenues for Ocean Monitoring**
2012	786	16.5 %	129.7
2015	911	11.4 %	103.9

Key Driver 1

Potential opportunities for intermediate users to reach out to clients that could benefit from EO solutions to monitor the ***rapidly changing characteristics*** (weather, currents, etc.)

Key Driver 2

Service providers have the opportunity to develop a wide range of applications on ***numerous sub-sectors*** (mapping of fishing zones, coastal protection, mapping of marine protected areas)

Key Driver 3

Several emerging trends, such as the impact of global warming on oceans and more specifically on marine resources, create ***new areas of actions for service providers.***

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

Overview of the EO market related to Ocean Monitoring activities

Current use of EO data in the Ocean Monitoring sector

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.

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 Fisheries Policies (CFP) in Europe.

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.

EO data contributes to **coastal protection through 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 . Satellites such as Envisat's Medium Resolution Imaging Spectrometer (MERIS) characterizes the complex missing of pollutants, suspended sediments and living and decomposing phytoplankton .

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 centres	• 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
Managing reef ecosystems	• Coral reef managers	• Facilitate decision-making to protect coral ecosystems • Facilitate conducting of extensive monitoring

Synthesis of current EO applications in ocean Monitoring

(Source: stakeholders consultation; PwC-Strategy & analysis)

The data flow along the Ocean Monitoring value chain

Value-added service providers (intermediate users) → **Final end users**

Acquiring Oceanographic data

Satellite data
- Jason satellites
- NASA satellites (NOAA)
- Landsat
- Sentinel data
- Data bought from private satellite operators (Cosmos, Radarsat)

In situ data
- Physical oceanographic, bathymetric and geophysical data

Processing Oceanographic data

Data processing platforms
- MyOcean
- Nephelae (IFREMER)
- SeaDataNet

In-house capabilities
- Combination of EO experts and specialised oceanographers
- Development of in-house capabilities on niche sectors, recruitment of researchers, investment in R&D
- Purchase of model licenses

Acquiring external capabilities
- Acquisition of companies specialised in radar data
- Establishment of partnerships with other private specialised entities

Development of software and specific products or applications

Aquaculture and fisheries products
- Origin tracing, algae and phytoplankton mapping, water depth charting and bathymetry, fish-shoals mapping, research on species behaviour, inventory and monitoring of aquaculture and fishery structures

Products and applications to protect living marine resources
- Habitats mapping, applications to support research on species movements and behaviours

Products for ocean monitoring and surveillance / coastal protection
- Weather forecasts, movements of marine soil, large waves forecasts and mapping

Used by a wide range of users

Diversity of end users
- Public/governmental bodies
- Users from the industrial fishing sector
- Researchers/ scientists

Training
- VAS companies may provide specific trainings to their clients who are not EO experts. CLS for example, has provided some technical assistance to its non-EO experts clients

The data flow along the Ocean Monitoring value chain

A diversity of data sources

The type of EO data required is very diverse. I**ntermediate users need EO data to have the widest geographical coverage** and the **highest revisiting time possible** for applications providing information for decision making. Medium Resolution is the most appropriate type of resolution for most of the applications developed. A **combination of public and private data are used in addition to specific in situ data** collected via very precise oceanographic sensors.

Various platforms combined to in-house expertise

Intermediate and/or end users use various platforms. The **Copernicus Marine Environment Monitoring Service (CMEMS)** provides regular information on the state of the physical oceans and seas. IFREMER has its own cloud for data processing platform, **Nephelae**, used for scientific research purposes. **SeaDataNet** is a standardized system to manage the data collected by the oceanographic fleets and automatic observation systems.

Tailored oceanographic products to respond to specific needs

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**.

Products benefit a wide range of end users

Most of end users are **governmental entities** such as ministries and agencies, sea management authorities. In the private sector, **civil engineering companies** or **fish farming companies are** examples of users of VAS products and applications on ocean monitoring.

Copernicus contribution to Ocean Monitoring related activities

The Copernicus Marine Environment Monitoring Service

Sentinel-1 & 2 data are used for very specific activities related to ocean 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.

The **Copernicus Marine Environment Monitoring Service (CMEMS) is an important contributor to the dissemination of Copernicus products** within the ocean monitoring value chain. Indeed, the CMEMS currently has approximately **between 5,000 and 6,000 users, 80% of which emanate from the public sector**. Approximately half of the users are scientific users. The other half is composed of professional users who use this data to develop commercial services: among those, approximately 20% very strongly need this information.

Sentinel-3 data will have the most significant added value on ocean monitoring. Indeed, Sentinel-3 has the appropriate technical specifications for ocean monitoring-related issues: it will provide wide-swath ocean color 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.

Copernicus strengths and opportunities in Ocean Monitoring

(Source: stakeholders consultation[1])

Copernicus programme 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 markets ***more aware of the potential benefits of EO*** in ocean monitoring-related activities.

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***.

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*** in the market.

[1] *Source: 7 stakeholders among which six private companies of different sizes and one national research center also delivering commercial services to private clients*

Copernicus contribution to Ocean Monitoring related activities

Economic impacts

- Stakeholders using Sentinel-1 & 2 data use it for very specific issues: **water quality, detection of micro bacteria, roughness features**
- The integration of Sentinel data has enabled service providers in ocean monitoring to **increase their productivity** (by 5% in the case of the ASIMUTH project)
- 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 (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 impacts

- The Copernicus programme has **created knowledge within the ocean monitoring sector**, by providing a flow of free data to service providers

Environmental impacts

- 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

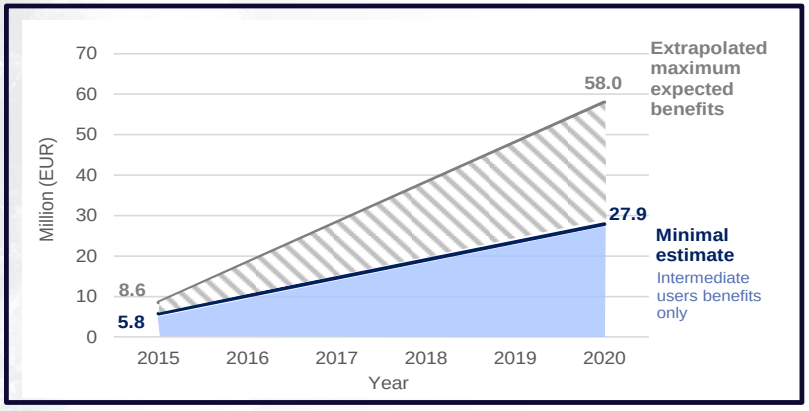
Copernicus contribution to Ocean Monitoring related activities

Copernicus current enabled revenues in Ocean Monitoring

Based on a sample of service providers covering a wide range of applications (coastal protection, marine biodiversity, support to aquaculture, mapping of marine protected resources, etc.), **Copernicus current enabled revenues are estimated to account for 6% of the intermediate users' revenues for ocean monitoring, representing EUR 5.8 to 8.6 million**. The current enabled revenues directly attributable to Copernicus may appear to be, at this stage, quite low but the study was performed only a year after the launch of the first Sentinel satellite. **The economic impact of Copernicus is expected to grow extremely quickly, up to EUR 58 million in 2020,** in particular thanks to the Sentinel-3 missions. In addition, these estimates do not include the benefits for the end users (e.g. fishermen), but only for the intermediate users (the downstream service providers).

(In EUR million)	EO interm. user revenues for OM	Copernicus enabled revenues for EO interm. users	GIS interm. user revenues for OM	Enabled revenues for GIS interm. users
2015	103.9	5.8	154.1	8.6
2020	117	27.9	243.3	58

Current and prospective revenues enabled by Copernicus in Europe for Ocean Monitoring downstream service providers



Source: The report on the Copernicus downstream sector and end user benefits, prepared by PwC for the European Commission, October 2016

*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 programme aims at establishing a management centre for marine resources that will enable to predict changes in fishery resources, fostering a sustainable use of marine resources in Indonesia while preventing unsustainable or illegal practices. It involves some of the major players of the downstream market such as CLS and Mercator Ocean.

More than 25 satellites provide the INDESO centre with data on a daily basis. It receives information from the Copernicus Marine Environment Monitoring Service. The 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 projected contribution to the global and European revenues in Ocean Monitoring

90% of the stakeholders' interviewed have indicated that they anticipate an increase in the enabled revenues directly attributable to Copernicus, to come mainly following the launch of Sentinel-3. 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**. 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** to monitor marine biodiversity for example. The creation of these products will boost the competiveness of the VAS companies and will have an impact on the distribution of the market, with a higher proportion of private users.

Case study

Copernicus helps fish and shellfish farmers monitoring toxic algal blooms

Context

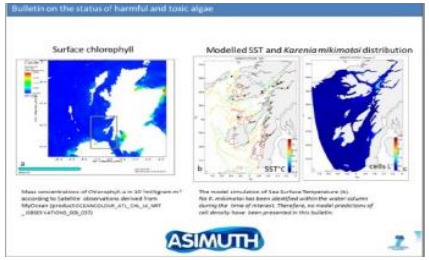
About **300 different types of algal blooms exist** and a quarter of these blooms are Harmful Algal Blooms (HABs), producing toxins. **HABs can have significant negative impacts**: as an example, one single toxic bloom caused the loss of 500,000 salmon in Shetland, an archipelago in Scotland.

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.

With **1.25 million tons of fish or finfish being produced every year**, the EU is the 8th biggest producer in terms of volume of aquaculture in the world.

Project

The **"ASIMUTH" project** has been set up in 2009 in order to respond to the demand for short-term **forecasts of harmful algal blooms events** along the European Atlantic coasts, using EO data. It tracks the origins of algal blooms using remote sensing satellite data, by 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.



Scottish HAB Bulletin Excerpt
(Source: the ASIMUTH project)

Results

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), improving their management strategies towards the impact of HABs with a particular focus on the sustainability of wild and farmed finfish and molluscan bivalve fisheries.

The aquaculture sector is increasingly exposed to international competition. An increased productivity and improved management practices will boost the supply of fish sustainably and **limit price fluctuations for raw material**.

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.

Copernicus enabled revenues

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. The forecasting system implemented within the ASIMUTH project targets 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,** representing a potential saving of USD 2.6 million (EUR 2.3 million).

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.**

5% gain in productivity for fish farmers thanks to the HAB monitoring system

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OIL & GAS

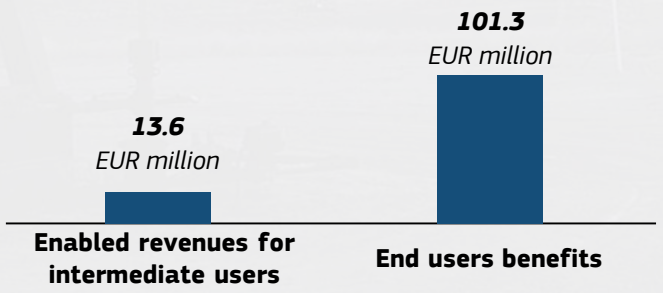
Key specificities

- The O&G value chain is the **most private sector oriented value chain**, with mostly private end users from the O&G industry.
- The **upstream O&G industry is heavily impacted by the fall of oil's price** which is negatively impacting the dissemination of EO in general, including Copernicus data and products, because the O&G industry is very traditional and risk averse when it comes to 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 widely spread among upstream O&G end users** when compared to other private sector value-chains. Interesting initiatives by ESA were developed in the field of O&G to foster the dissemination of the use of EO data.
- The largest share of value derived from the Copernicus data and products is derived from the end users **(the O&G companies themselves)**, not from EO downstream/intermediate users.
- **Most of the industry has already switched to the GIS products & services**. Upstream O&G players are in most cases using imagery incorporated in more complex GIS products, including EO (all resolution), UAVs data, in-situ data, internal data and statistics, etc.

Copernicus applications

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

Copernicus economic impact (2015)



The Oil & Gas market is mainly driven by the upstream industry

O&G market main figures

Based on EARSC data (2015)[1], more than 8% 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, as **the main driver of the market is the price of oil** which fell since June 2014.

(In EUR million)	**Overall EO downstream market [1]**	**% of the overall market for Oil & Gas [1]**	**Intermediate users' revenues for Oil & Gas**
2012	786	11.5 %	90.4
2015	911	8 %	73

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

O&G market trends

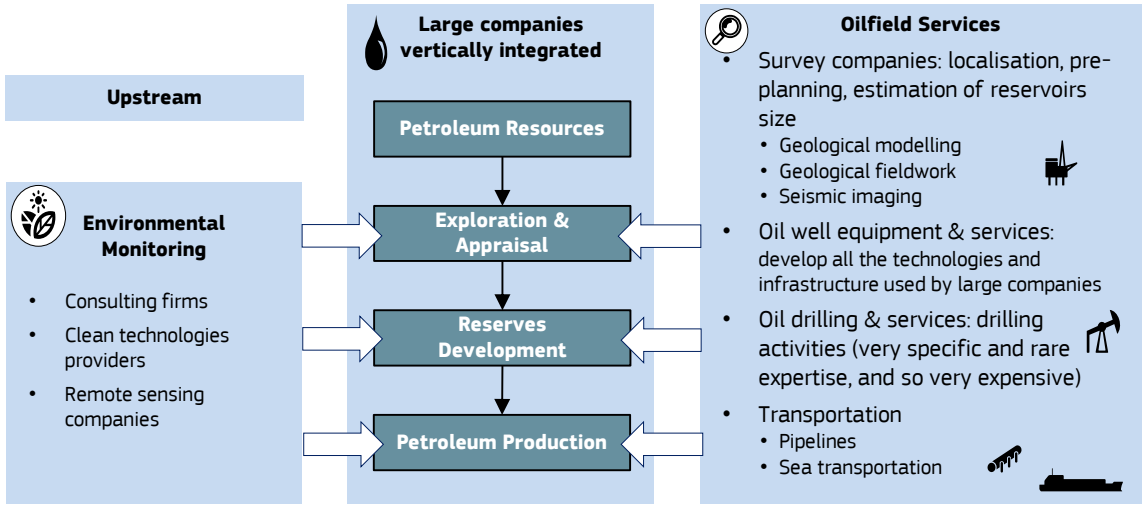
Most O&G users have their own in-house EO capabilities or are currently building them. This trend should contribute to a faster dissemination of Copernicus data when the oil price will grow up again. This trend should also offer interesting economic growth in the future (5-10 years). The majority of O&G players mostly use **GIS products and services,** including EO and Copernicus data. EO only products and services are used in very specific niche markets: EO is a tool among others in the O&G industry.

The digitalisation era is also impacting the O&G upstream industry. A virtual ecosystem for GIS products and services exists and most players in this industry are capitalizing on this opportunity to get access to very deep and useful business intelligence thanks to **digital platforms**. Such platforms are a **game-changer for the industry** where the user can easily integrate different sources of data available into web-platforms with his own data – O&G companies have huge repositories of data and statistics on all their activities – leading to very high value-added business intelligence for them.

The O&G upstream value chain

The upstream part of the O&G industry is at the roots of the O&G market. Investments made in the upstream trickle down through all the other parts of the value chain.

The O&G upstream industry is **heavily consolidated, with very large players involved in most of the supply chain and dominating the market**. The figure below 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:



Characterisation of the O&G upstream supply-chain

(Source: PwC-Strategy& analysis)

GIS platforms and products are the root of the EO value chain for the upstream Oil & Gas industry

The EO value chain in the O&G upstream industry

The chart on the right presents the process of value creation in the O&G upstream value chain (in a simplified manner). It should be noted however that, depending on the company and the environment being prospected, the usage of EO data varies extensively.

A large proportion of O&G players interviewed are very interested in digital platforms to access EO data, products and services (see example below).

*The **Earth Observation broker Energy platform** is a communication device which aims at connecting the O&G industry and EO suppliers on a web-based platform.*

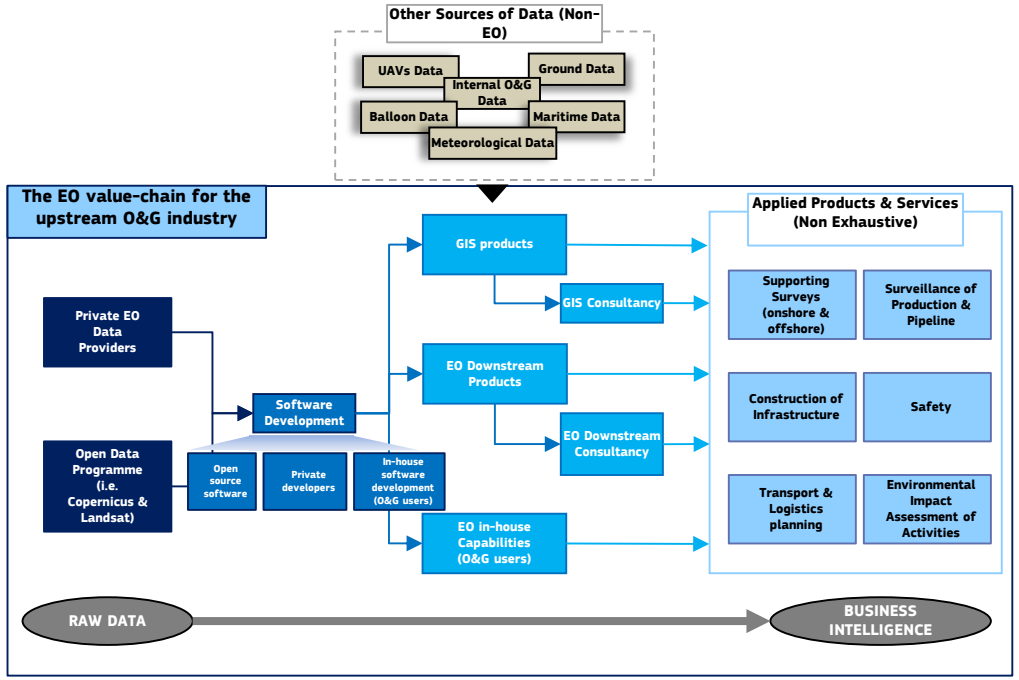
The Earth Observation broker Energy platform is a two-year project funded and operated by ESA, with plans to let the platform openly and free-of-charge for the users. It is built on the recommendations and lessons learnt from the EO4OG initiative (see case study for more details).

The aim is to spark, through public support, private investments into the ecosystem. Though the platform was originally designed for O&G players, the vision of ESA is to extend it to more sectors, pushing for the development of a cross-fertilisation platform. The Energy platform will not offer any products itself on the platform but only act as a broker.

The platform will at first only provide private EO players' products and services but ESA also aims to provide in future Sentinels data, Copernicus products (involving more than only Sentinel data), UAVs products and all other types of data.

EO value chain for the upstream O&G industry

(Source: PwC-Strategy & analysis)



Overview of EO applications in the upstream Oil & Gas industry and perspectives for Copernicus

Current use of EO data in the O&G sector

Earth Observation has been used among the O&G industry for a long time, although the importance of EO data in business models varies extensively from one company to another. For some players, EO is a tool among others whereas for other–players, EO is part of their competitive advantage in the market. The use of EO data follows a golden rule in the O&G industry: if an activity is sporadically performed, the activity is outsourced to a third party; if not, the activity 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.

EO in the O&G industry involves in most cases a mix of very different resolutions of satellites data, both in terms of spatial and temporal resolution. Very high resolution data are used for very specific and local applications whereas low/medium data and high resolution data are used for large area monitoring or to calibrate local scope surveys or mapping. **EO is mainly used to support and calibrate existing activities, and improve planning activities** to increase the accuracy and efficiency of exploration and drilling activities. However, it is not a substitute for ground surveying or boat monitoring

Copernicus strengths and opportunities in Oil & Gas

(Source: stakeholders consultation[1])

EO is already ***widely spread*** in the O&G industry, which should facilitate the dissemination of Copernicus products since most of the O&G players have their own in-house activities

Copernicus data/products are not substitutes for the tools currently used in the O&G upstream industry. They are ***complementary to other tools***, including UAVs data.

Availability of ***large archives*** of Copernicus data should stimulate the utilisation of data over the coming years

The ***Energy broker platform*** initiative developed by ESA should foster the use of EO data, including Copernicus data and products within the O&G industry

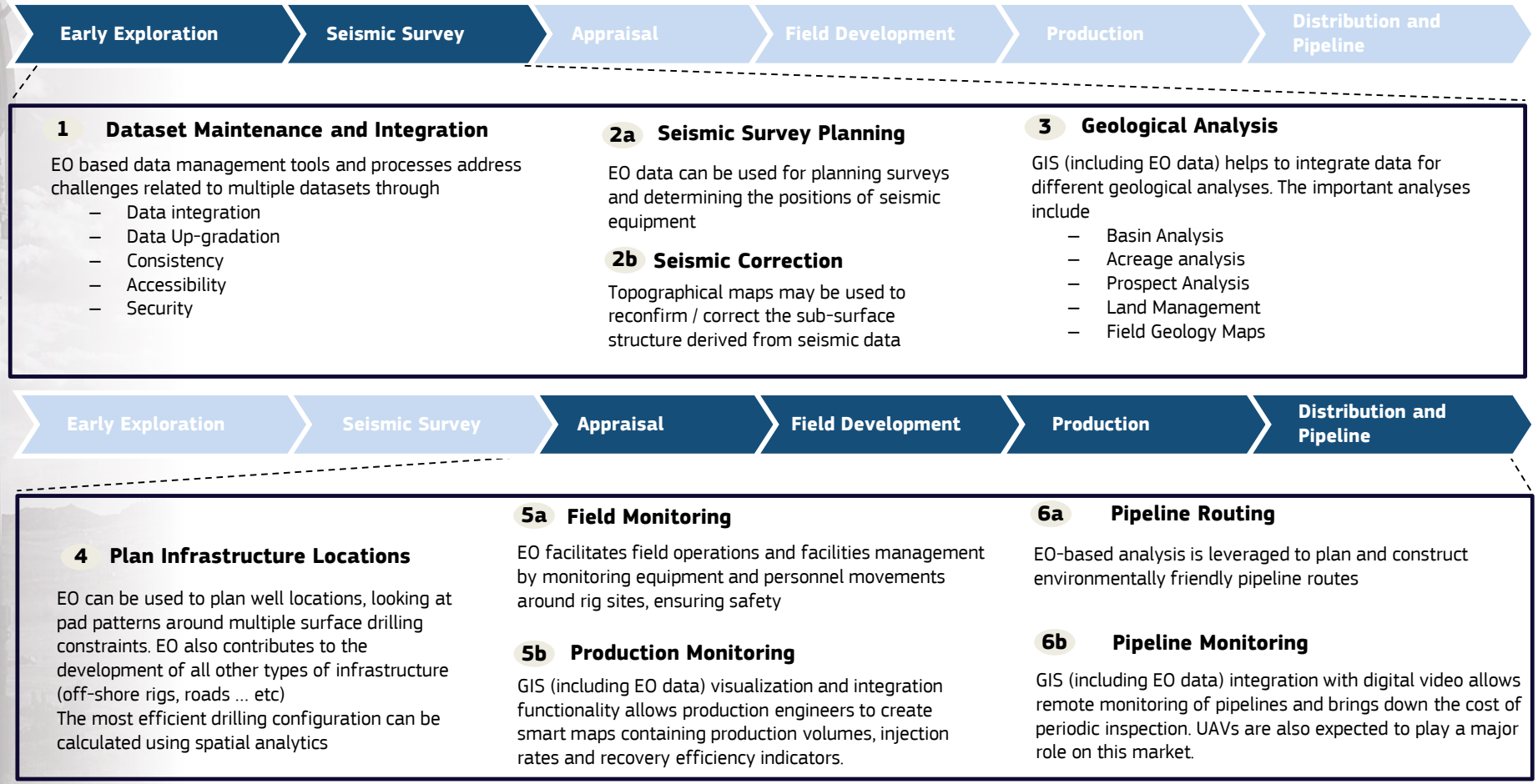
GIS products are already widely used in the O&G upstream industry. The more the Copernicus programme will collaborate with GIS providers, the more Copernicus data/products will be used

[1] *Source: Stakeholder consultation based on interviews with a sample of stakeholders from the O&G sector: 17 stakeholders interviewed among which O&G companies, VAS companies, O&G associations*

Overview of EO applications in the upstream Oil & Gas industry

Types of EO applications in the upstream O&G industry

During Early exploration and Seismic surveying, EO data are used, together with other sources of data, to improve planning and correction. EO enables O&G players to do large scale prospecting in a much more efficient way for both onshore and offshore exploration. Using EO data also allows for greater confidentiality compared to sending helicopters or boats over specific areas of interest. The second part of the figure below presents at a very high level how EO is used from appraisal to distribution as well as in pipeline development and surveillance. EO is particularly greatly used in infrastructure development and safety to reduce risks of disasters to protect workers and to be environmentally responsible.



How Earth Observation is used along the O&G upstream supply-chain

(Sources: expert interviews)

Copernicus revenues related to the Oil & Gas sector

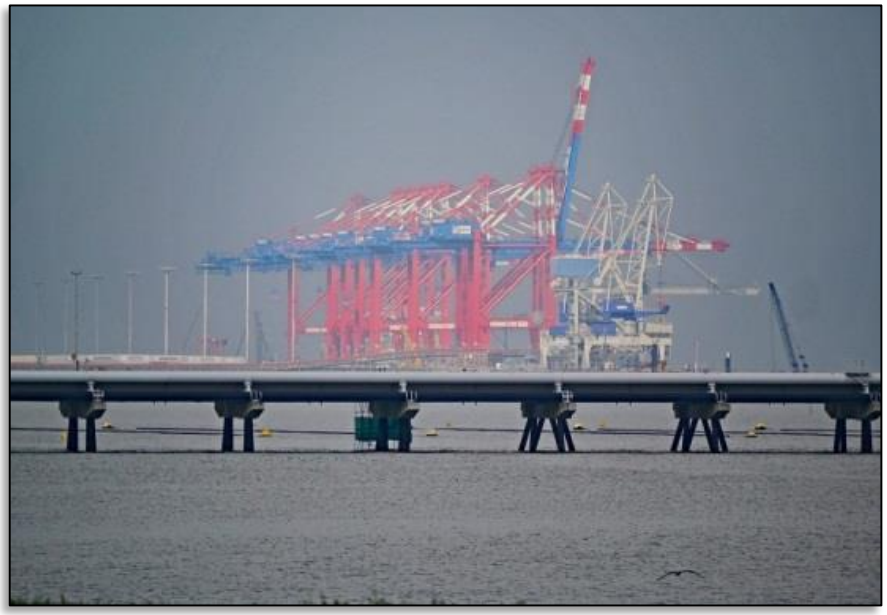
Copernicus current and projected enabled revenues in the Oil & Gas sector

The revenues enabled by Copernicus for the O&G upstream industry is already as high as 115 million in 2015 and is likely to increase up to EUR 312 million by 2020.

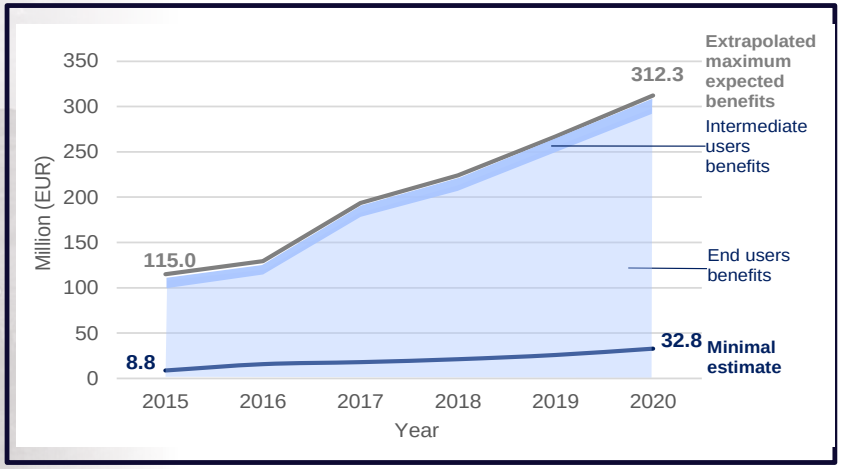
These figures include EO intermediate players, integrated players and Oilfield companies only. No market figure was found for the environmental monitoring firms, even if the market is expected to grow, offering interesting business opportunities in the coming years.

The strong projected increase in market value between 2015 and 2020 is mainly due to the increased penetration rate of Copernicus data and products which is currently very low among large integrated and oilfield services companies. This estimation is also connected to expected growth of the oil price in the coming years.

The minimal estimations takes only into account the benefits reported by the companies that were interviewed for this study. The "maximum estimation" extrapolate these benefits to the entire O&G sector.



Current and prospective revenues enabled by Copernicus in Europe for the Oil & Gas value chain (downstream/intermediate and end users)



Source: The report on the Copernicus downstream sector and end user benefits, prepared by PwC for the European Commission, October 2016

The potential value of Copernicus for the O&G value chain:

€ 115 million in 2015

*of which € 107 million for **end users** (O&G companies)*

€ 312 million by 2020

*of which € 300 million for **end users** (O&G companies)*

Case study

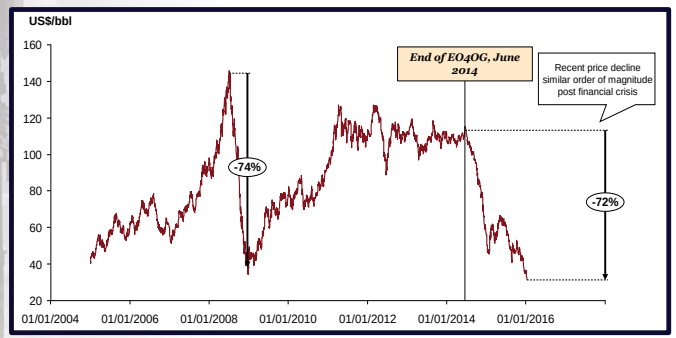
The EO4OG project helps understanding and structuring the Oil & Gas EO downstream market

Context

The oil price has been falling drastically over the past couple of years. This has very negatively impacted the penetration rate of EO products in the O&G industry, including those using Copernicus data. However, all O&G players are very interested in EO products produced internally or bought to EO downstream players. The main issue comes from O&G companies not willing to invest in new products with such a low price of oil.

Brent crude daily price, January 2005 - January 2016

(Sources: Bloomberg; PwC-Strategy& analysis)



Project

Recently **ESA, EARSC and the International Association of Oil and Gas Producers (IOGP) have developed new collaborations to bring together EO and O&G communities and stimulate the use of Copernicus**. The Oil and Gas Earth Observation group (OGEO) was founded in 2010 and led to the building of an OGEO web-portal hosted by EARSC, where members of both communities can exchange best practices and issues to be solved.[1] The EO4OG project is born following this initiative and ESA has decided to fund 4 projects.

Results

EO4OG is made of 4 two-year projects, which have led to very interesting results. They have identified **needs, requirements and challenges faced by the O&G industry.** They also suggested a **list of products** the EO downstream market should develop to fix these challenges, covering:

- ✓ Exploration & Drilling activities
- ✓ Transports & Logistics
- ✓ Risk of Disasters
- ✓ Infrastructure Construction and Safety
- ✓ Environmental monitoring

The quantification of Copernicus data contribution was based on a sample of 12 European and Canadian firms, including integrated players, oilfield services companies and EO downstream players.

	Enabled revenues (M€)	Proportion of total enabled revenues
Total market effect	7.98	91.20%
Total commercial effect	0.70	8.00%
Total organisational effect	0.07	0.80%
Total enabled revenues	**8.75**	**100.00%**

Copernicus enabled revenues

EUR 8.75 million value of Copernicus data for this O&G upstream industry sample (12 companies)

[1] *Source: OGEO platform website, consulted November, 12 2015.- Link: http://www.ogeo-portal.eu/*

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RENEWABLE ENERGIES

Key specificities

- This chapter focuses on solar, wind, hydro and biomass renewable energy sources (RES), which 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 147 billion turnover in the EU in 2015 and employed 8.1 million people in 2012.
- 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 estimated to be worth **EUR 22.7 million in 2015.**
- A minimal estimation of the **revenues enabled by Copernicus** on the global renewable energies market is **EUR 2.7 million in 2015.**

Copernicus applications

- Solar and wind energy production forecasting
- Solar and wind farm maintenance
- Biomass production monitoring
- Tracing biomass along the value chain
- Dam maintenance and management of the level of water
- Renewable energy site selection

Copernicus economic impact (2015)

1.8 – 2.7
EUR million

Enabled revenues for intermediate users

Example:

Copernicus-based forecasts generate 50% more benefits to solar energy producers than the traditional meteorological forecasts.

End users benefits

Overview of the EO market related to Renewable Energies

A new and growing market

The European 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 10 million in 2011 and EUR 12.1 million in 2015[1].

The market with the highest potential 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 EO-based products.

A fragmented market

The main intermediate users in Europe in the field of renewable energy are VAS companies or research centres. The VAS companies are SMEs that are either specialised in a type of EO product, as in 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, experts of PV energy production.

The EO market of wind energy is not mature yet and the intermediate actors in this sector are mainly research centres, such as DTU and research and development units of major VAS companies.

Historically, the end users of EO applications were the small companies operating in the renewable energy production sector. Nevertheless, incumbent energy companies (either private or semi-public) have progressively absorbed a large number of small actors and are now important end users as well.

Key Driver 1

There is an ***increasing demand*** for energy over the globe

Key Driver 2

The increased competition in the renewable energies market, drives the end users to find solutions to ***cut costs and optimise production***

Key Driver 3

Some VAS companies are preparing to enter the ***energy trading market***.

Key Driver 4

Biomass energy producers are increasingly required to report the way they manage their biomass and have to trace it

(In EUR million)	**Overall EO downstream market [2]**	**% of the overall market for Renewable Energies [2]**	**Intermediate users' revenues for Renewable Energies**
2012	786	2.8 %	22.2
2015	911	2.5 %	22.7

[1] *Source: European Renewable Energies Federation*
[2] *PwC/Strategy& analysis including the results of : EARSC (2015). A survey into the State AND Health of the European EO Services Industry. Prepared by EARSC under assignment from ESA, September 2015.*

Overview of the EO market related to Renewable Energies

Current use of EO data in the Renewable Energies sector

EO-based data is used to forecast, nowcast and reanalyse the production of energy.

Early detection of faults reduces costs for **optimised on-going and on-demand maintenance** of production sites. Traditional maintenance also often requires expensive software for preventive maintenance whose costs can be avoided with EO-based maintenance. For dams too, EO radar data enables on-going remote maintenance by detecting micro failures in the dams or small landslides in the surroundings.

Forecasting potential energy production and analysis of areas based on EO provides **useful information on site plants, dams and biomass reservoirs, highlighting the most-productive locations and facilitating estimation of the environmental and social impacts of production**.

EO improves the production forecasts for the **optimal integration of traditional and renewable energy supply systems** into electric power grids.

A key issue linked to biomass and biofuels is the optimisation of production on a sustainable basis. EO data can both help to **monitor biomass and to ensure homogeneous and accurate reporting to public institutions.**

Applications	End users	Benefits
Site selection and design of plants or facilities	• Suppliers to energy providers • Energy providers	• Environmental and social impacts • Selection of the most productive energy production site
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 providers • Energy and carbon traders	• Optimised trading revenues
Environment monitoring	• Energy providers • Local and national authorities	• Reduced negative impact of a plant or piece of infrastructure on the environment, and health
Tracing biomass and monitoring production	• Biomass producers • Local and national authorities	• Compliance with regulations

Synthesis of current EO applications in the sector of Renewable Energies

(Source: stakeholders consultation)

The data flow along the Renewable Energies value chain

Value-added service providers (intermediate users)

Acquiring EO data

EO Data
- Copernicus (Copernicus Atmosphere, Marine Environment and Land Monitoring Services)
- National missions Meteorological satellites

Historical information
- ENVISAT

In situ data
- Measured output

Plant characteristics

Socio-economic data

Processing EO data

Data processing platforms
- ESA Urban TEP, PEPS

Systems and data logging devices
- Area-specific

In-house capabilities
- Data assimilation
- High-end climate modeling and computing
- Area-specific knowledge
- SAR expertise

Development of software and specific products or applications

Site selection and plant output forecasting
- Production of forecasts (e. g. irradiance forecasts)
- Output estimates (e. g. based on plant characteristics coupled with forecasts)
- Mappings and elevation maps (e.g. wind farms, biomass)

Efficiency monitoring
- Comparisons of actual output with the estimates

Carbon sequestration estimation

Final end users

Benefits of EO for end users

- Siting plants and facilities (energy potential, environmental and social impacts)
- Optimised design
- On demand maintenance
- Better integration into the grid
- Economic analyses ~~for~~ of investment
- Life cycle considerations
- Certification of the origin and sustainability of wood biomass

The data flow along the Renewable Energies value chain

EO data enables to extend and harmonise in situ datasets

The intermediate users procure a wide range of different EO data for the different EO applications mentioned above:

- Aerosol analysis (CAMS)
- Digital elevation models (CLMS)
- Land cover type and change data
- Land surface temperature data
- NRT parameters as input for mesocale modelling
- Snow cover extent data
- Surface solar irradiance (CAMS)
- Wind observations (CMEMS)
- Clear sky products (including CAMS McClear, a service estimating irradiation under clear-sky)

Products are developed mainly to support site selection, output forecasts and efficient monitoring for each RES

PV production forecasting is based on historical data, near-real time data, and meteorological and atmospheric data (cloud, water vapour, aerosols, dust), in particular clear sky models. The first step is to calculate power production as if there were no clouds. The quantity and quality of the clouds can then be analysed and the production forecast adjusted accordingly. For **EO-based PV plant maintenance**, any discrepancy between observations and forecasts indicates that there is a fault either of the monitoring sensors or on a panel.

For **wind turbines**, ground-based data is first used to validate the satellite data and then is extrapolated to different heights. For on shore farms, land use data is used to model the studied field and radar data is used to model winds. For offshore farms the CMEMS provides data on sea surface winds.

Land cover type and change data, snow cover extent data (fusion of radar and optical imagery), rivers and lakes parameters and infrastructure stability indicators are useful for **hydropower forecasts and risk management.**

For **biomass** management, VAS companies produce carbon stocks estimates and accurately identify the impacts of production

Uses are diverse

Energy providers, suppliers to energy providers and electricity grids managers are the main end users of EO products related to RES.

State and local decision makers receive site selection analyses for new facilities for authorisation.

Copernicus contributes to the Renewable Energies sector

Most of the Copernicus data used by the RES arise from Sentinel-1A and Copernicus Core Services

Sentinel-1A allows VAS companies operating in the field of renewable energies to develop **new products** as it provides data that are not available from any other source. This is the case for example in the detection of slow landslides close to dams, as Sentinel-1A gives an unprecedented level of accuracy.

Several Copernicus core services are also used to deal with renewable energies:

- **Copernicus Land Monitoring Service (CLMS)** provides global observation of wind characteristics, such as speed, field or stress. Corine Land cover is used for positioning wind turbines, on a site where energy production is maximised, and that is far enough from housing but close enough to the grid in order to minimise the loss of energy in transportation. Copernicus EUDEM (Digital Elevation Model) is also used to study the relief and so the areas where there is wind., which is of interest when undertaking Energy resource assessment for selecting wind farm sites.

- **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 areas affecting solar radiation conditions (e.g clouds, aerosols, water vapour and ozone). CAMS also provides 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.

- **Copernicus Marine Environment Monitoring Service (CMEMS)** provides information on sea surface winds, which is useful for selecting off-shore wind farm sites.

Copernicus strengths and opportunities in the Renewable Energies sector

(Source: stakeholders consultation[1])

CAMS McClear service is ***simple to use***	Copernicus provides the right data for ***PV production forecasting***. The data are also already ***computed and corrected***.
Biomass energy producers are increasingly required to report on the way they manage their forests and have to trace their biomass emissions.	EO data ensure ***homogeneous*** geographical coverage. They are also ***stable in time*** which make them suitable for site selection
Intensive competition in the sector pushes towards greater ***optimization of energy production***, for which EO data is of great help.	EO-based forecasts have more value-added in ***isolated zones*** such as islands.

[1] *Source: 12 stakeholders including 7 private actors (6 small and 1 micro companies), 2 public organisations, 2 research centres and 1 association*

Copernicus contributes to the Renewable Energies sector

Economic impacts

- For solar energy, **CAMS products increase the quality of solar power production forecasts**.
- Copernicus offers free data with the right frequency, cover and continuity requirement for biomass monitoring, helping site manager to optimize their production.
- *With Sentinel-3, the redundancy of data will be higher, which is key for the quality of deformation analyses (expected)*
- *Sentinel-4 will provide new atmospheric and solar radiation data, thus enabling the creation of new products for solar energy production (expected)*

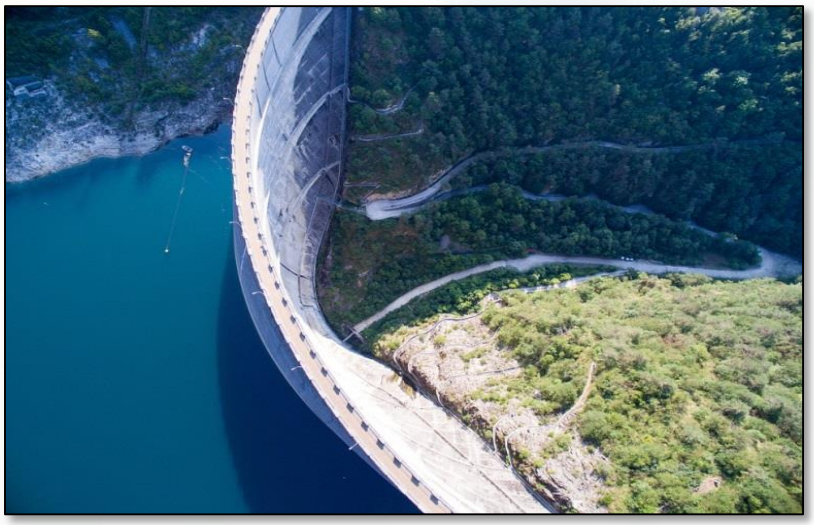
Social impacts

- 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.

*TRE, an Italian company, develops an application to monitor the stability of dam structures and the surrounding areas called **SqueeSAR**.*

This InSAR technique identifies deformation occurring on dam structures, supporting buttresses, surrounding slopes and downstream areas. Deformation maps can be used as inputs to risk models, important in identifying dangers to areas downstream.

SqueeSAR can detect displacements on dams to millimeter accuracy, identifying movements that could indicate structural weaknesses. Deformation data allows engineers to determine whether dam movements are within acceptable design limits.



Environmental impacts

- Copernicus helps to **reduce the emissions of greenhouse gases by triggering the production of renewable energies.**

Strategic impacts

- Copernicus contributes to increased production of renewable energies by making them more cost-efficient and more productive , thus contributing to **reducing dependence to fossil fuels**

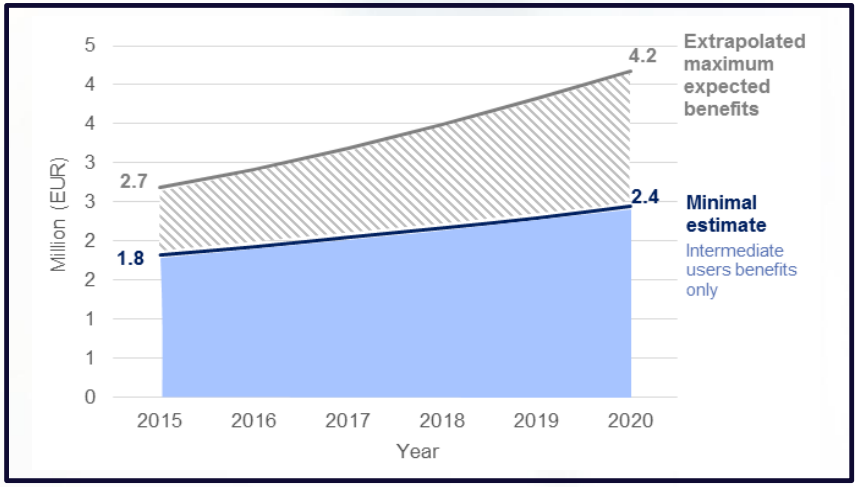
Copernicus revenues related to the Renewable Energies sector

Copernicus current enabled revenues in the Renewable energies sector

Based on a sample of EO service providers covering a wide range of renewable energy applications, **Copernicus current enabled revenues are estimated to account for 8% of the revenues of intermediate users (i.e. the downstream providers), representing EUR 1.8 to 2.7 million. This could rise up to EUR 4.2 million in 2020.** The current enabled revenues directly attributable to Copernicus may appear to be, at this stage, quite low but the study was performed at an early stage of the Copernicus programme (only one year after the launch of the first Sentinel satellite) and the estimates are voluntarily extremely conservative. In addition, these estimates do not include the benefits for the end users (e.g. the energy producers), but only for the intermediate users (the downstream service providers).

(In EUR million)	EO interm. users revenues for RES[1]	Copernicus enabled revenues for EO interm. users	GIS interm. users revenues for RES	Copernicus enabled revenues for GIS interm. users
2015	22.7	1.8	33.4	2.7
2020	30.5	2.4	52.2	4.2

Current and prospective revenues enabled by Copernicus in Europe for Renewable Energies downstream service providers



Source: The report on the Copernicus downstream sector and end user benefits, prepared by PwC for the European Commission, October 2016

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

Case study

How Reuniwatt uses Copernicus to monitor solar power production

Context

Reuniwatt is a start-up of about 15 people in La Reunion island which created **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: using CAMS McClear
- H+6 hours: using 90% of data from Meteosat and a clear sky model using CAMS atmospheric parameters.
- H+24 hours: which will soon use CAMS raw data.

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.**

Project

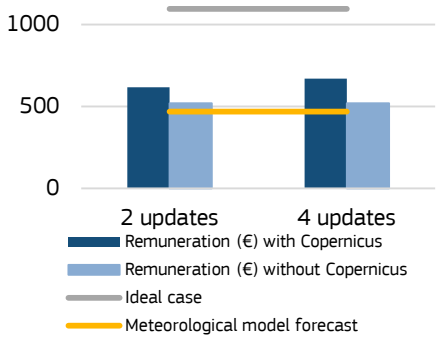
PV electricity producers are legally bound to provide the electricity grid manager with forecasts 24 hours ahead of the production.

Soleka forecasts provide crucial information for **minimising surcharges and regulatory penalties for PV electricity providers** which are held responsible for providing to the electricity grid operator the quantity of electricity they have forecast the day before.

Uncertainties of day-ahead forecasts increase with the time horizon so intraday forecast updates enables an anticipatory adjustment mechanism that reduces the cost of inaccurate forecasts. **Satellites, including Copernicus, provide data for the next 6 hours and thus, provide more reliable information than T+24 hours meteorological data based forecasts.**

Results

Reuniwatt has analysed the results of a fictional PV plant based on the data collected on the day of 8 April 2013 in Carpentras, south of France.



Remuneration of the PV energy producer depending on the use or not of Copernicus data

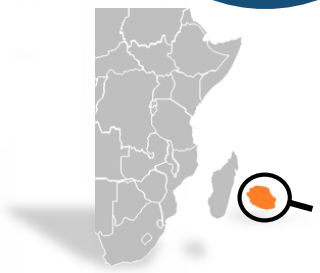
(Source: Cros, S., Buessler, E., Huet, L., Sébastien, N., Schmutz, N.(2015))

15%
costs reduction thanks to this Copernicus based service

Copernicus enabled revenues

Reuniwatt research demonstrates that the quality of forecasts increases significantly: **a classic clear sky model has an error rate of 6% whereas a clear sky model using real-time CAMS values has an error rate of 3%.**

This improved forecast can lead to a **2% increase of the PV energy producer remuneration**. Reuniwatt demonstrated that the use of Copernicus and satellite based forecasts **generates 50% more benefits than the traditional meteorological forecasts**.



2%
additional revenues

50%
improved forecasts accuracy

European Commission | Copernicus Europe's eyes on Earth

AIR QUALITY

Key specificities

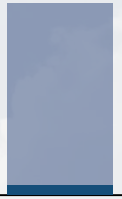
- EO data on atmospheric composition has been introduced in air quality analysis models only recently; these **models are historically based on meteorological data, air composition statistical data and measurements**
- **Intermediate users** are mainly **meteorological and environmental agencies or publicly-funded 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 for 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 limited in the Western countries: this is due to the fact that the needs of intermediate and 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)**, which provides different reanalyses and near-real time analyses and forecasts related to the atmospheric composition, is the most used Copernicus product in the field of air quality analysis

Copernicus applications

- Monitor air quality on specific territory
- Inform the population
- Trace and forecast pollutants fluxes
- Support policy making for public authorities
- Assess impact on environment and public health
- Control the impact on local air quality of private activities and the compliance with the legal limit values
- Identify potential pollution sources

Copernicus economic impact (2015)

0.03 – 0.19
EUR million



Enabled revenues for intermediate users

Example:

Copernicus enabled a 60% improvement in the accuracy of the analysis of the impact of trans-boundaries pollutants on air quality

End users benefits

Overview of the EO market related to Air Quality

A key sector domain for human health

Air pollution is among the major challenges of the 21st century, having **an unprecedented impact on human health, climate and ecosystems**. It is, with climate change, one of the only environmental risks that is shared by the entirety of the world population. In 2013 around **5.5 million people died as a result of air pollution**. Its economic impact is significant: i**n 2010, it represented EUR 15 billion from lost work days, EUR 4 billion from healthcare costs and EUR 1 billion from damage to buildings in the EU alone**.

According to EARSC 2013 Industry Survey, Atmosphere is the Copernicus service holding the least interest in terms of business opportunities for the companies interviewed. There are a number of reasons for this:

- **Most of the 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**

However, according to other studies and to our stakeholders consultation the air quality monitoring market is expected to grow at a rate of 8.5% per annum from 2016 to 2021[2]. The main business opportunities lie in specific markets for which **customised in situ data** is used to complement satellite data.

There is also an increasing demand for air quality analysis at the level of the individual. 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 players are developing different kinds of **individual sensors on connected objects** which could provide in an instant very customised analysis on the air quality.

Key Driver 1

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

Key Driver 2

There is an increasing demand for air quality information at ***street level***. This is possible by extrapolating the information of ***in situ sensors combined with EO data***.

Key Driver 3

There are increasing ***reporting obligations*** because of the strengthening of regulations on air quality monitoring.

(In EUR million)	Overall EO downstream market [2]	% of the overall market for Air Quality [2]	Intermediate users' revenues for Air Quality
2012	786	1.7 %	13.36
2015	911	0.2 %	1.82

[1] *Source: EARSC (2015). A survey into the State AND Health of the European EO Services Industry. Prepared by EARSC under assignment from ESA, September 2015.*
[2] *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*

Overview of the EO market related to Air Quality

Current use of EO data in the Air Quality monitoring sector

ENVISAT was the only satellite capable of providing relevant information for the monitoring of air quality in the early-2000s. EO satellites today are capable of measuring emissions of carbon, ozone, and numerous other air pollutants including particulate matter but also particles such as those from dust, smoke, and pollen.

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 users 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.

*During the episode of high sulphur dioxide in Paris after the **eruption of the Eyjafjöll volcano** in 2010, EO data has been used to understand whether restrictions on road traffic would have an impact on air quality.*

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 centres	• Identify the polluters • Scientific research
Local scale air quality analysis	• Companies such as industries, airports, waste management companies etc.	• Local environmental impact assessment
Hot spots detection	• Institutions	• Identify the polluters • Identify the critical areas in a region

Synthesis of current EO applications in the Air Quality sector
(Source: stakeholders consultation)

The parameters for the Air Quality sector along the EO value chain

Value-added service providers (intermediate users) → **Final end users**

Acquiring Air Quality EO data

Raw data
- Copernicus
- Aura, Aqua, Terra (MOPITT)
- EUMETSAT
- MODIS Aerosol
- AIRS CO (total column) and Sulfur Dioxide (day and night)
- OMI
- NOAA
- ENVISAT (Schiamachy)
- Japanese Space agency
- Chinese Space agency

In situ data
- Background stations
- Balloons

Processing Air Quality data

Data processing platforms
- CAMS, CLMS, Space agencies warehouses, services of specialized companies

Data combining methods
- Data integration
- Data fusion
- Data assimilation

Required skills
- EO data processing
- Mathematical models
- Atmosphere physics
- Meteorlogy
- Health

Development of software and specific products or applications

Nowcast
- Near-real time maps of specific air polluants or overall air quality at a globall, regional or urban scale.

Forecast
- Forecasts of specific air polluants or overall air quality at a global, regional or urban scale.

Hindcast
- Simulation of past air fluxes

Benefits of EO for end users

Input for public and non-profit players
- Estimate the efficiency of a policy and target the efforts
- Measure the impact of air pollution on health,, etc.
- Trace back air pollution flows over the globe
- Measure the gap with the targets
- Inform the population
- Integrate into climate systems

Input for individuals' decisions
- Be aware of the risk and take decisions accordingly

Support private actor' decisions
- Monitor their impact
- Sectorial applications

The parameters for the Air Quality sector along the EO value chain

Mixing the EO data with other sources

The **in situ data in use** comes from 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 specialised associations etc.

For applications in urban areas, some data can be provided by local authorities, 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.

The key role of CAMS

In the field of air quality, Copernicus' most used service is the **Copernicus Atmosphere Monitoring Service**. CAMS 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.

Several models to build a product

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.

There are various challenges linked to the use of EO data for analysing air quality. For example, the resolution is sufficient 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.

Various applications

Air quality forecasting provides **key tools for public authorities** to assess the impact of air pollution, identify the best measure to adopt, etc.

Individuals want to have information on air quality but are not ready to pay for it. **Private companies** can monitor their compliance with the limit values. **Research organisations** use this information to better understand the climate.

The growing role of Copernicus services in the Air Quality domain

The Copernicus Atmosphere Monitoring Service

Most of the intermediate users of the air quality sector do not directly download Sentinel data but use CAMS. Most CAMS users are based in Europe and are mainly **European-level decision makers**. Some **private players** 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 trans boundary pollution fluxes which impact the local air quality**. **CAMS is the only tool providing this type of information.**

For example, AirTEXT, an initiative operated by CERC, a small private company, 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 also used to analyse and forecast the pollution fluxes that come to London from the rest of Europe.

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.**

The next Sentinels will improve the accuracy of the air quality forecasts. In particular, Sentinel-3 will provide additional data on dust aerosol, particulate matters and water vapour and Sentinel-4 and 5 will bring additional information on the chemical composition of the troposphere. Sentinel-5P will be useful to trace pollutants fluxes.

Copernicus strengths and opportunities in Air Quality management

(Source: stakeholders consultation[1])

Copernicus' **continuity** enables operational applications such as urban air quality monitoring	Copernicus provides ***reliable*** data, notably data on pollen and UV with a ***quality*** which has no equivalent
CAMS regional model is operational, reliable, and the data is adapted to the range of pollutants required by users	There is demand for systems to ***trace back pollutant fluxes*** over the globe
Air quality models are ***constantly being improved***, maximising the potential benefits of Copernicus. ***New niche markets*** should emerge	Local authorities may have legal ***obligation to monitor air quality*** in the future, expanding the market for VAS companies
New players may want to buy ***air quality forecasts***, such as insurance companies, players in the health sector or events organisers.	There is an ***increasing need*** for air quality monitoring tools in developing countries and in particular in ***India and in China***

[1] *Source: 14 stakeholders dealing with air quality management, including 6 private actors, 7 public actors (space agencies, meteorological agencies, environment agencies and ministries) and 1 research centre also developing commercial applications*

The growing role of Copernicus services in the Air Quality domain

Economic impacts

- Copernicus allows time savings **as it enables to identify hotspots**
- The small and micro companies operating in the air quality sector interviewed for this study consider that around **7% of their revenues can be attributable to Copernicus**
- **Copernicus** improves the quality of the forecasts at the scale of city by up to 20%
- *Copernicus can help take opportunities in niche markets (tourism, etc.) (expected)*

Social impacts

- 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 impacts

- Better monitoring of air quality **helps to 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 impacts

- As Copernicus provides a set of harmonised data, it facilitates the **coordination at the international, European, national and local levels to implement the right policies**
- Copernicus helps **monitoring the air quality over areas which did not have any tools to do so** and facilitates the control of data provided by these countries, improving **transparency**
- *Copernicus could help to **trace back the polluters** through inverse modelling (expected)*

***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.

Plum Air reports in different cities *(Source: www.plumelabs.com)*

Copernicus revenues related to Air Quality management

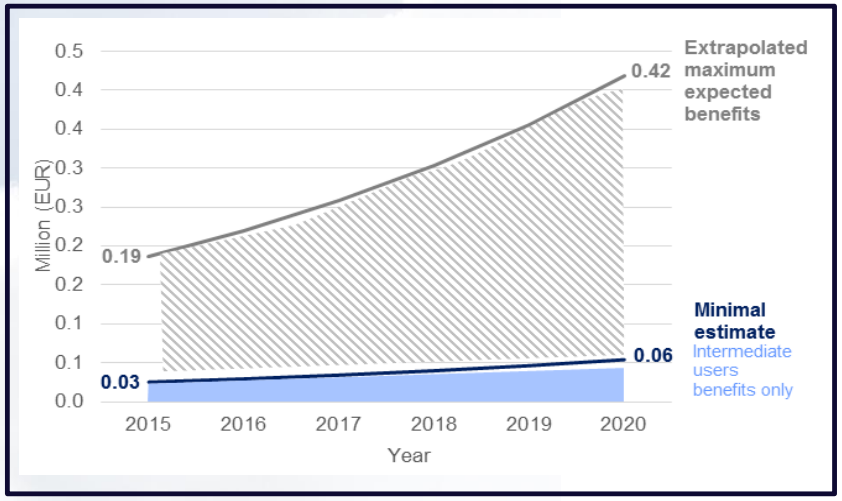
Copernicus current enabled revenues in Air Quality management

In 2015, the revenues in the field of Air quality are estimated to be of EUR 0.36 million for EO companies. According to our stakeholder consultation, Copernicus data represents between 7% of the data used. Thus, in 2015, revenues enabled by Copernicus in the field of air quality can be estimated to be around EUR 25,000 (minimal estimate). To obtain a maximum estimate, we run the same calculation using the GIS market for Air quality as a basis (**EUR 2.67 million in 2015).** This yields a Copernicus-enabled revenue for the Air quality downstream service providers of EUR 0.19 million. The current enabled revenues directly attributable to Copernicus may appear to be, at this stage, quite low but the study was performed at an early stage of the Copernicus programme (only one year after the launch of the first Sentinel satellite) and the estimates are voluntarily extremely conservative.

Though they were not quantified here, benefits for end users (e.g. municipalities or citizens) also exist, linked to the impact of air pollution such as sick leaves, healthcare costs etc.

(In EUR million)	EO interm. users' revenues for AQ[2]	Copernicus enabled revenues for EO interm. users	GIS interm. users' revenues for AQ	Copernicus enabled revenues for GIS interm. users
2015	0.36	0.03	2.67	0.19
2020	0.54	0.06	4.18	0.42

Current and prospective revenues enabled by Copernicus for Air Quality downstream service providers



Source: The report on the Copernicus downstream sector and end user benefits, prepared by PwC for the European Commission, October 2016

Copernicus projected contribution to the global and European revenues in Air Quality management

The Air Quality monitoring market is expected to grow at a rate of 8.5% per annum from 2016 to 2021[1], while the relative importance of Copernicus will also grow. By 2020, we estimate the Copernicus-enabled to range between EUR 0.06 and 0.42 million in 2020.

Indeed, the penetration rate of the municipalities market should rise. Then, more players are expected to buy Air Quality forecasts such as insurance companies (as input data for risk 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. A diversification of the geographic provenance of the users is also expected. Most of the VAS companies consulted are anticipating a significant increase of their extra-European sales of Copernicus-based products in the coming years and already have carried out operational projects in countries outside of Europe.

[1] *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*

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

Case study

Copernicus for monitoring the air quality in cities down to the street level by Numtech

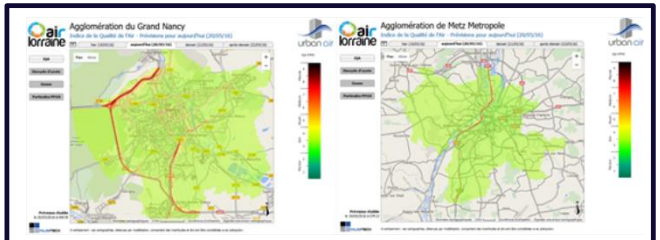
Context

NUMTECH is a French start-up, of about 20 people, specialised in the simulation of the atmosphere. One of its main activities is to develop 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), located all over the world, and especially outside Europe and North America where there are less rival initiatives.

Cities already equipped with Urban Air in France
(Source: www.numtech.fr)

Project

Urban Air is based on the atmospheric dispersion software ADMS URBAN developed by the SME CERC. It is being deployed over Paris in 2016, in the frame of a demonstrator public-funded project "Env&You". This brought together various initiatives such as Ambientic, CapDigital, Forum Virium Helsinki, TheCivicEngine and Inria. **Urban Air makes air quality forecasts down to the street level.**



An operational Urban Air in the city of Nancy (France)
(Source: www.numtech.fr)

Results

CAMS **is the only initiative providing information on long distance pollutant fluxes for free and at a global level.** It is particularly useful for regions such as Eastern Europe, South America, Africa, and Middle East where only few surface measurement data are available.

Copernicus enabled NUMTECH to **reach cities where a limited amount of data was available.** 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 trans-boundary movements, Copernicus improved the precision of Urban Air by 60%, and we can evaluate an improvement of 10% to 20% to more local pollutants.**

60%
improved precision of Urban Air by Copernicus

Copernicus enabled revenues

About **10% of the data used in Urban Air stem from Copernicus**. In particular, it represents **most of the data used to analyse the background pollution**, which makes it one of the key inputs of Urban Air. NUMTECH expects from €1 to 10M of annual revenues on the Env&You project, so **Copernicus should generate from €100K to €1M of annual revenues on this project.**

On its initial market, Urban Air should enable NUMTECH to **double their turnover in the short term on markets abroad**, **where the lack of background information on air quality is an obstacle.** Copernicus should generate revenues from **new markets** by selling environmental data to new types of clients (sports, real estate parties, etc.) **10 job positions will thus be created.**

ANNEXES

Methodology of the study

This Market Report summarizes the main findings from two studies, prepared by PwC for the European Commission and published in 2016: (1) *The report on the Copernicus downstream sector and end user benefits*, and (2) *The report on the socio-economic impact of Copernicus*. The figure below summarises the methodology used for the analysis of the downstream and end user benefits.

Phase	Approach used	
Characterisation of the value chain	• The first step consists in understanding and characterising the composition of each value chain. The aim is to be able to design specific value chain framework to understand how many stages are involved in each one. • This 1st round of interviews have been performed with experts from Copernicus (or any other EO data source) and the processing industry.	
Mapping the players in the value chain	• Identification of all the relevant players involved in a particular value chain • Production of a database of players with the relevant information (size of players, type of players and geographical repartition)	
Pick a representative sample of organisations	• The sample should be large enough to be considered as representative (based on the size, type and geographic repartition) • It will depend on the industry and on the mapping coming from the previous step.	

Engage organisations (public & business) in direct interviews	• Understand the particular context of the firm
	  • History
	  • Engagement in the space programme
	  • Use of EO data
	  • Impact of Copernicus data availability (open data)
	  • Existence of substitutes
		Qualitative data

	• Gathering quantitative data
	  • Revenues
	  • Investments made to support business development
	  • Market shares
	  • Paternity of EO data (minimal estimation, different type of effect on business model)
		Quantitative data

Extrapolation of results	• Extrapolation depending of the sample (size and representativeness) • Extrapolation per type of company (using the same average figures)	

Copernicus Enabled revenue

A microeconomic approach was used for the estimation of the revenues enabled by the use of Copernicus data and services. This quantitative estimation was run only for:

- The intermediate/downstream users for the eight value chains
- The end users in three value chains (Insurance, Oil&Gas and Urban Monitoring).

It was assessed using a BETA inspired methodology. Such an approach allows dealing with a complex phenomenon that differs strongly from one end user to another. This methodology is able to catch the diversity and the complexity of effects derived from the use of EO data and requires direct interviews with a representative sample of end users in the different value chains under scrutiny.

In practice, the methodology involved picking a representative sample of organisation and defining with them the impact of Copernicus on their business, discussing in particular three types of effect :

- **Market effect:** the availability of Copernicus data enables an innovative offer for the users by increasing sales of existing products; increasing sales of new products on existing markets; and creating a new department/company on a new market.
- **Commercial effect:** the availability of Copernicus data enables the development of a new or better commercial network for the users by developing new networks and partnerships.
- **Organisational effect:** the availability of Copernicus data enables organisational improvements within the organisation.

With this method, a range of paternity coming from the Copernicus is estimated. On this range, the smallest figure is taken in order to provide the most robust estimation of the paternity coming from the use of Copernicus data. The aim of this methodology is indeed to show the existence of the phenomenon rather than providing an exact figure, to prevent overestimation of benefits.

Once the impact of Copernicus on the representative sample is estimated, it is extrapolated to the entire sector. For the intermediate/downstream users, the reference sector is the EO sector (minimal estimation) or the GIS sector (maximum estimation)

Societal and wider impacts analysis

Societal and wider impacts include all socio-economic impacts that are quantifiable but not monetary in nature. Examples are 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.

In such context, no proper methodology is perfectly suitable and a mix of qualitative and quantitative approach had to be used. In particular, this assessment was 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.

List of acronyms

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
AQ	Air Quality
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 Environment Monitoring 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	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 Platform
TM	Thematic Mapper
UAS	Unmanned Aircraft Systems
UAV	Unmanned aerial vehicle
UHI	Urban Heat Islands
UM	Urban Monitoring
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

About the authors

The European Commission

The European Commission (EC) is responsible for management of the European satellite Earth Observation programme Copernicus, including:

- management of funds allocated to the programme,
- supervising the implementation of all activities related to the programme,
- ensuring clear division of responsibilities and tasks in particular with the European Space Agency and the delegated entities,
- ensuring proper reporting on the programme to the Member States of the EU, to the European Parliament and to the Council of European Union

The Copernicus programme is entirely financed by the European Union.

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About the Copernicus Market Report

This Market Report summarizes the main findings from two studies, prepared by PwC for the European Commission and published in 2016: (1) *The report on the Copernicus downstream sector and end user benefits*, and (2) *The report on the socio-economic impact of Copernicus*. The interested reader will be able to find a wealth of additional details in these two studies.

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