FIRE | European Forum for Earth Observation

D4.3 Strategic EO Sector Development Roadmap

WP4 – EO Sector Development Strategy

Authors: Evenflow srl

Date: 27.10.2022

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 869634.

Full Title	**Forum for Innovation and Research in Earth Observation**			
Grant Agreement No	869634		**Acronym**	FIRE
Start date	01.12.2019		**Duration**	36 months
EU Project Officer	Ms. Izabela Freytag			
Project Coordinator	Ms. Natassa Antoniou (EARSC)			
Date of Delivery	**Contractual**	M34	**Actual**	M35
Nature	Report		**Dissemination level**	Confidential
Lead Beneficiary	Evenflow SRL			
Lead Author	Eleftherios Mamais		**Email**	lefteris@evenflow.eu
Other authors	Ruuta Skujina, Nico Thom, Georgeta Galusca, Daire Boyle, Phillip Harwood, Tim Heijmann, Lauriane Dewulf			
Reviewer(s)	Natassa Antoniou, Christopher Oligschläger			
Keywords	roadmap, strategy, Earth Observation, research, development, innovation			

Document Revision History				
Version	**Issue date**	**Stage**	**Changes**	**Contributor**
1.0	27/10/2022	**Draft**	Initial draft	EVF
2.0	28/10/2022	**Draft**	Minor comments and edits	EARSC
3.0	30/10/2022	**Final**	Final	EVF

Disclaimer

Any dissemination of results reflects only the authors' views and the European Commission is not responsible for any use that may be made of the information it contains.

Contents

Table of Figures

Executive Summary

FIRE, the European **F**orum for Innovation & **R**esearch in **E**arth Observation has set out to create a solid understanding of the "now" of the European Earth Observation (EO) sector to shape a concrete vision of its "tomorrow" with concrete actions proposed. During the past 34 months, a constant open dialogue with stakeholders from six key sectors – agriculture, wind energy, urban development, infrastructure, marine & maritime, raw materials – took place to identify challenges in their sectors, current use or potential of EO to address these, and research and innovation actions required to support EO uptake in the short- and mid-term. This allowed building a community of innovation actors from across the value chains of different sectors and the EO industry. Focus group discussions and a series of events, the FIRE Forum 1 & 2 allowed for coordinated interaction with and between these actors to answer key questions:

- **Where are we now?** What is the current state-of-play in the six FIRE sectors (key policies, major challenges, R&D trends)? To what degree has EO supported the development of solutions in these sectors?
- **Where do we want to be?** What is the future we are trying to shape and what is the role of EO in it? Where do we want to direct investment to?
- **How can we get there?** Which actions shall we undertake as a community of practitioners (both EO and non-EO)? Which collaborative activities shall we carry out to achieve the desired future we envisage?

The efforts made to answer these questions ultimately led to the development of this roadmap document, a collaborative and integrated European research and innovation strategy that aims to guide the development, delivery and uptake of EO services. More than 30 actions have been defined forming the roadmap in and across each of the addressed sectors. These were selected to enable the involved actors to take meaningful action towards maximising the benefits of EO.

This roadmap aims at better informed decisions among these actors: policy makers drafting future work programmes, multipliers (e.g. associations and networks) to guide their members with regards to EO capabilities, and researchers and companies in response to market needs and opportunities. To that end, we have pointed out which actors need to be involved in supporting and carrying out the actions and in which timeframes.

Overall, this roadmap shall pave the way for informed follow-up activities which will further promote user-driven and collaborative approaches to research and innovation and ultimately help deliver EO solutions and their uptake across sectors for the benefits of economy and society.

1 Why do we need a roadmap?

1.1 General context

Our world stands at a critical juncture. Decades of harmful human activity have brought the disastrous reality of climate change and its effects onto our doorstep. With the frequency and magnitude of extreme natural hazards serving as a constant reminder (IPCC 2018), humanity needs to act as one to limit dangerous global warming, reduce its reliance on fossil fuels, and **implement sustainable policies affecting all economic activities**. All this has been exacerbated by the impact of the COVID-19 pandemic, disrupting supply chains and challenging business processes. An even higher level of urgency is observed as a result of Russia's invasion of Ukraine and the subsequent hardships and global energy market disruption.

Against this backdrop it becomes apparent that **sustainability is no longer just a trendy keyword but an absolute necessity**, especially when considering the projected increase of the global population to 10 Billion by 2050, two-thirds of which will be living in urban areas (UN 2018). This means not only a soaring demand for food (50% more than in 2013 levels - FAO 2017); it also means further environmental impact and degradation. We need to rethink and overhaul our current means of producing food, consuming natural resources, and living in cities. This applies to activities not only on land but also in our seas and oceans, whose health we need to safeguard through sustainable Blue Economy activities (see G7 Blueprint).

These reflections form an integral part of the global initiatives or policy frameworks that will see our world's transition to a more sustainable future. Thus, on a global level, this is embedded in the 2030 Agenda on Sustainable Development; the agenda is anchored by 17 Sustainable Development Goals (SDGs), associated targets, and a global indicator framework. Collectively, these elements enable countries and the global community to measure, manage and monitor progress on economic, social and environmental sustainability across a wide variety of sectors: agriculture, water management, climate change adaptation, clean energy, sustainable cities, etc. In addressing the challenges faced in each of these sectors, the **importance of data cannot be overstated**; this is best captured in the dedicated report requested by the UN Secretary General in 2014: "*Data are the lifeblood of decision-making and the raw material for accountability. Without high-quality data providing the right information on the right things at the right time; designing, monitoring and evaluating effective policies becomes almost impossible*".

Similarly, at EU level, these considerations are echoed in the **EU's strategy for a transition to a future characterised by digital leadership and environmental sustainability**. For instance, the EU Green Deal, underlines that "*Accessible and interoperable data are at the heart of data-driven innovation. This data, combined with digital infrastructure and artificial intelligence solutions, facilitate evidence-based decisions and expand the capacity to understand and tackle environmental challenges*". In that respect, Earth Observation (EO) holds a prominent role. As stated in Art. 76 of the 2030 Agenda *"...We will promote transparent and accountable scaling-up of appropriate public-private cooperation to exploit the contribution to be made by a wide range of data, including earth observation and geo-spatial information..."*.

The achievement of the SDGs, the pursuit of the goals set out by the EU Green Deal, but also the response to the aforementioned pressures in the global geopolitical context can all be supported by a **mission-oriented approach.** In Europe, it is precisely such an approach that has laid the foundations for the Horizon Europe Programme and the work to be done within it up to 2027. At the heart of this approach lies the recognition that strategic missions (such as those encompassed within the SDGs) act as opportunities to steer investment-led growth, but on the other hand fall short of producing real impact if they are not translated into ambitious yet realistic challenges. Thus, whilst the missions on adaptation to climate change, soil health and food, healthy oceans, seas and waters, and climate-neutral and smart cities provide directionality to R&I efforts, they require a **proper bottom-up representation on challenges faced by government agencies, local and regional authorities as well as corporates in the various economic sectors.** Equally important for the success of such an approach is the **optimal exploitation of cutting-edge technological solutions such as those enabled by Earth Observation**. These solutions generate significant benefits across a wide range of domains as exhibited nicely in the recent EUSPA EO and GNSS Market Report or in activities such as the ESA Sentinel Benefits Study. And for many of these solutions a key driver is the exploitation of the power of Europe's one-of-a-kind Copernicus Programme and advancements achieved through a long series of GEO-related activities.

It is precisely the combination of these aspects that "gave birth" to FIRE – the European Forum for Earth Observation, as a "platform" where researchers, governmental organisations, corporates, and entrepreneurs can exchange and shape together the future of Earth Observation R&D in Europe. And it is precisely the combination of the aforementioned aspects, i.e. the proven value and untapped potential of EO in addressing global challenges, that calls for a **strategic EO sector development roadmap.** Thus, this report presents in a concise manner the results of 3 years of intensive interaction among different stakeholders in the form of a roadmap for each of the sectors that have been in scope. This is explained below followed by instructions on how to read this document.

1.2 FIRE Roadmap methodology: Knowing the "now" is key to shaping "tomorrow"

Over the past 3 years, FIRE has set out to investigate the current state of affairs with regards to EO adoption in six selected sectors and to outline future perspectives for this adoption to be increased and the corresponding benefits to be maximised. This process has been driven by asking a few key questions and then systematically attempting to find the answers:

- **Where are we now?** What is the current state-of-play in the six FIRE sectors (key policies, major challenges, R&D trends)? To what degree has EO supported the development of solutions in these sectors?
- **Where do we want to be?** What is the future we are trying to shape and what is the role of EO in it? Where do we want to direct investment to?
- **How can we get there?** Which actions shall we undertake as a community of practitioners (both EO and non-EO)? Which collaborative activities shall we carry out to achieve the desired future we envisage?

To understand the "now" and be able to shape the "tomorrow", FIRE has combined extensive involvement of key stakeholders from the various sectors with rigorous analysis on the side of consortium partners. The methodological approach followed in FIRE and culminating with the production of the present roadmap is visualised below, followed by brief description of each of the main methodological steps.

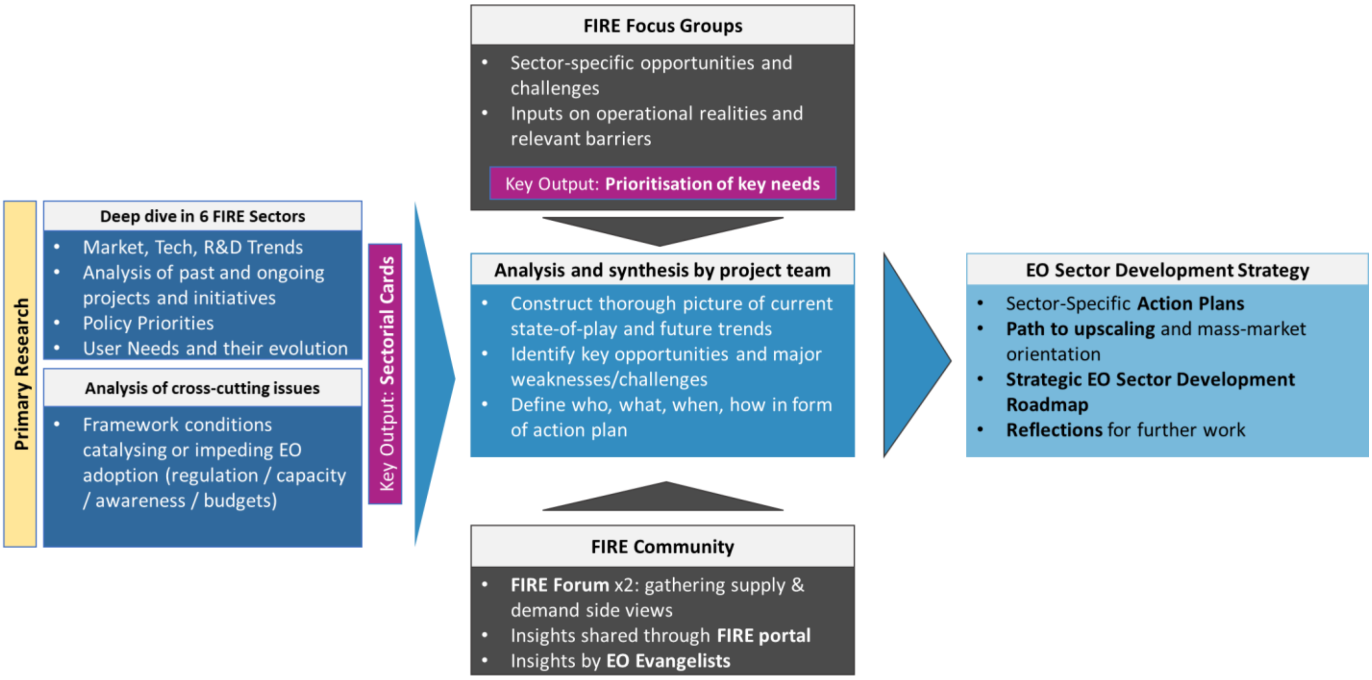


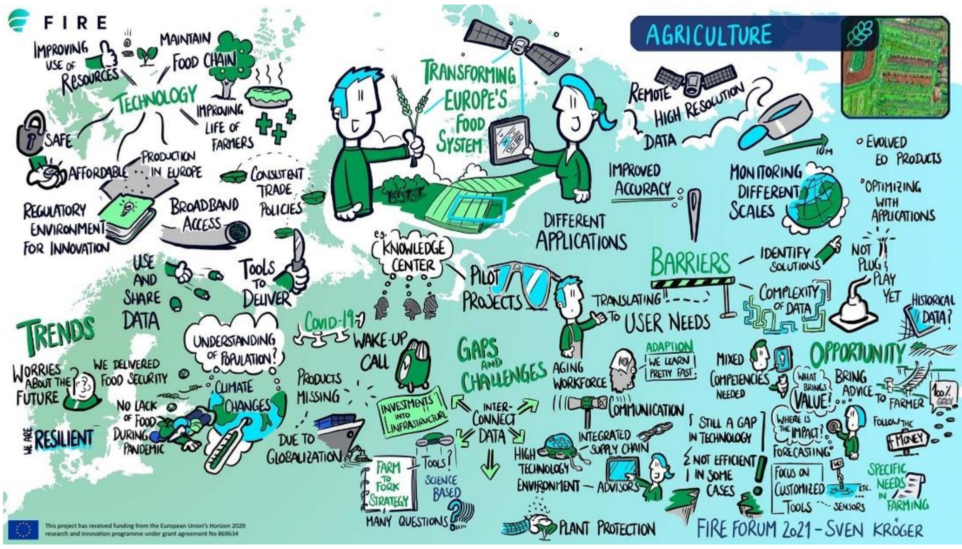
Figure 1: Methodology for the development of the roadmap

Constructing a thorough picture of the current state of play

From its very beginning FIRE set out to capture the current state of play in each of the 6 sectors. This involved a thorough analysis of market, tech and R&D trends, a detailed account of relevant projects and initiatives, and an extensive desk research around policy priorities and user needs. **Sectorial cards** were produced for each sector serving as input to the discussions with key experts from the six sectors in the **Fire Focus Groups**. A brief summary of relevant aspects is presented in the present document in the "Where are we now?" subsections for each sector.

Identifying key opportunities and major weaknesses/challenges in each sector

FIRE has placed strong emphasis on identifying key opportunities for the adoption of EO solutions in each sector and recognising the main challenges preventing this from materialising. These aspects have been extensively discussed with the members of the FIRE Focus Groups; the findings of these discussions have been nicely visualised in a series of infographics as shown below.


FIRE
AGRICULTURE
IMPROVING USE OF RESOURCES
MAINTAIN FOOD CHAIN
TECHNOLOGY
IMPROVING LIFE OF FARMERS
SAFE
AFFORDABLE
PRODUCTION IN EUROPE
CONSISTENT TRADE POLICIES
REGULATORY ENVIRONMENT FOR INNOVATION
BROADBAND ACCESS
TRANSFORMING EUROPE'S FOOD SYSTEM
REMOTE
HIGH RESOLUTION DATA
10M
EVOLVED EO PRODUCTS
OPTIMIZING WITH APPLICATIONS
IMPROVED ACCURACY
MONITORING DIFFERENT SCALES
DIFFERENT APPLICATIONS
USE AND SHARE DATA
TOOLS TO DELIVER
KNOWLEDGE CENTER
PILOT PROJECTS
BARRIERS
IDENTIFY SOLUTIONS
NOT PLUG & PLAY YET
HISTORICAL DATA?
COMPLEXITY OF DATA
TRANSLATING TO USER NEEDS
TRENDS
UNDERSTANDING OF POPULATION?
COVID-19
WAKE-UP CALL
GAPS AND CHALLENGES
AGING WORKFORCE
ADAPTION
WE LEARN PRETTY FAST
MIXED COMPETENCIES NEEDED
OPPORTUNITY
WHAT BRINGS VALUE?
BRING ADVICE TO FARMER
WORRIES ABOUT THE FUTURE
WE DELIVERED FOOD SECURITY
CLIMATE CHANGES
PRODUCTS MISSING
INVESTMENTS INTO INFRASTRUCTURE
INTER-CONNECT DATA
COMMUNICATION
STILL A GAP IN TECHNOLOGY
WHERE IS THE IMPACT?
FORECASTING
FOLLOW THE MONEY
NO LACK OF FOOD DURING PANDEMIC
WE ARE RESILIENT
DUE TO GLOBALIZATION
FARM TO FORK STRATEGY
TOOLS?
SCIENCE BASED
MANY QUESTIONS
HIGH TECHNOLOGY ENVIRONMENT
INTEGRATED SUPPLY CHAIN
ADVISORS
NOT EFFICIENT IN SOME CASES
FOCUS ON CUSTOMIZED TOOLS
SENSORS
SPECIFIC NEEDS IN FARMING
PLANT PROTECTION
FIRE FORUM 2021 - SVEN KRÖGER
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 869634


FIRE
MINDSET/SKILLS
• THINK IN PROJECTS
• STOP SILOS
• EDUCATE PEOPLE HOW TO USE DATA
• VALUE BASED THINKING
• KNOW YOUR NEEDS
COST
VALUE
INFRASTRUCTURE
BIG AMOUNT OF DATA
EO DATA
• EXISTING DATA
• OPEN SOURCE
• REAL TIME DATA
• RESOLUTION
USE
PLANNING
PRESER-VATION
DEVELOP-MENT
GREEN DEAL
OPERATION
MAINTE-NANCE
80% OF THE NETWORK ARE O.K.
SELF DRIVING CARS
BE EFFICIENT
SELL SERVICES NOT TECHNOLOGY
SHARE BENEFITS
TOOLS
• SOFTWARE
• HARDWARE
• ALGORITHMS
METRO
TAKE A CLOSER LOOK
USE OF STREETS AND TUNNEL NETWORK
UNDERSTAND
• IMPACTS
• REMOTE PLACES
• UNDER THE SURFACES
INFRASTRUCTURE CONNECTS EVERYTHING
CONDITIONS OF ASSETS
• IMAGES
• OPEN SOURCE DATA
• ARCHEOLOGICAL RISK
MONITOR CHANGES
• DAMAGES
• CLIMATE CHANGE
• AGING
SHOW CASES
AWARENESS
• HOW TO USE THE DATA
• SHOW VALUES
• SHOW POSSIBILITIES
BEST PRACTISE
EO
IMPROVE EXISTING TECHNOLOGY
• INVOLVE SUPPLIERS
LEARN FROM OTHER SECTORS
THINK BIG
CONNECT SECTORS
DON'T THINK IN SINGLE PROJECTS
FIRE FORUM 2021 - GABRIELE SCHLIPF
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 869634


FIRE
MARINE - MARITIME
TRENDS
NEEDS
ILLEGAL FISHING
TOURISM
INVEST AT SEA
WE CAPTURE TIME & SPACE
BUILD COMMUNI-TIES
WE BUILD THE FUTURE
LEGAL FRAME WORK
COASTAL ECO SYSTEM
CLIMATE CHANGE
GROWING INDUSTRY
SMART TECHNOLOGY
RELIABLE DATA
EASY ACCESS TO DATA
BUILD SPECIFIC SERVICES
DIVERSE ACTIVITIES
REACHING A SUSTAINABLE BLUE ECONOMY
AT SEA INFRASTRUCTURE
GOOD INTERFACE
UNDERSTAND THE PROBLEM
IMAGE
BIG AREA
USAGE
• COST & RISK REDUCTION
• MAKE DECISION
• LARGE SCALE
LEGAL OR ILLEGAL
POSSIBLE ACCIDENTS / POLLUTION
TECNICAL NEEDS
• MODULAR
• SECURE
• INTEGRATION
• DIGITALIZATION OF BUSINESS
TECHNOLOGY SOLUTION
SKILLED USER
TALK TO CUSTOMER
SATELLITES
• COMMUNICATION
• OBSERVE-MONITOR
• MOVING IMAGES
• FORECAST
UNDER WATER
TALK TO CLIENTS
INNO-VATE
GET FASTER IN PROVIDING DATA
EARTH INTELLIGENCE
SMALL AND BIG OBJECTS
+ MOVING
INNOVATION SUPPORT
FIRE FORUM 2021 - GABRIELE SCHLIPF
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 869634

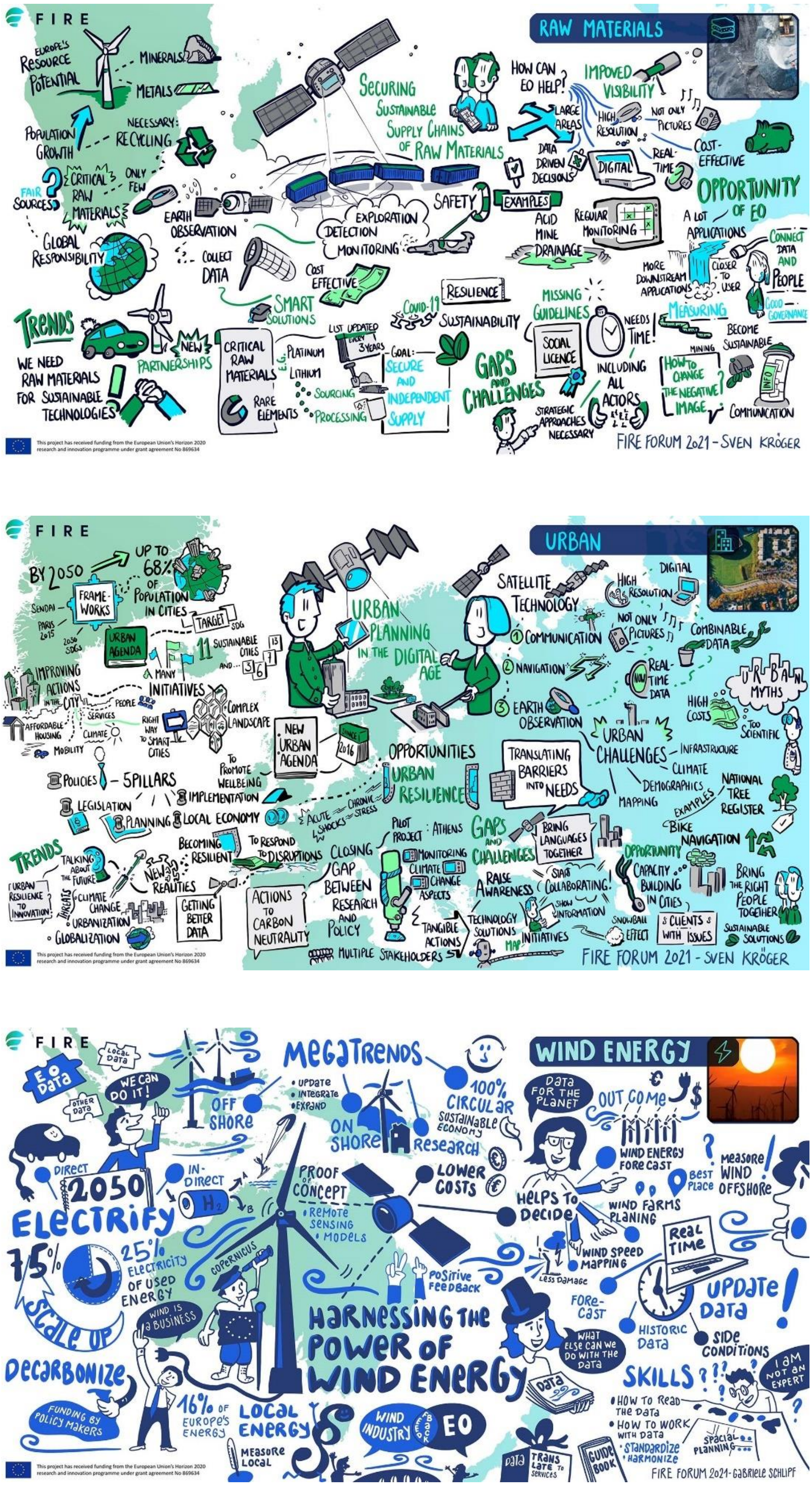


Figure 2: Visualisations of the outcomes of the 1st FIRE Forum

Analysing cross-cutting issues

Besides diving deeply into each sector, FIRE has sought to shed light to cross-cutting issues. This involved analysing the relevant regulatory framework, the state of awareness among key stakeholders, their capacities in relation to operationally adopting EO solutions in their workflows and the availability of budgets that can be mobilised for relevant activities.

Defining who, what, when, how in the form of an action plan

All of the above has been combined with first-hand insights from users (from both governmental organisations and corporations), service providers, institutional actors (e.g. EC policy officers from the competent units) and multipliers (e.g. Trade Associations, Sectorial Fora) to produce a clear definition of what needs to be done (**setting objectives and scope**), how shall it be pursued (**which modalities, which programmes, which budgets**), by who (**stakeholders involved**) and in which timeframes (**short vs medium term**). These considerations have informed the content presented in this document; more details on how to navigate it are offered below.

1.3 What is the ultimate aim of this document and how to read it

The ultimate aim of this document is to **provide evidence-based recommendations** that can (i) inform future work programmes of Horizon Europe and, potentially, other relevant instruments, (ii) inspire collaborations among stakeholders in the various relevant value chains in each sector, (iii) constitute solid reference points for drawing broader strategic paths that aim at maximising the impact of EO activities – especially in relation to Copernicus and EuroGEO.

To that end, the roadmap is structured as follows:

- Chapters 2-7 present the **sectorial roadmaps** for **Marine** (chapter 2), **Urban Development** (chapter 3), **Agriculture** (chapter 4), **Wind Energy** (chapter 5), **Raw Materials** (chapter 6) and **Infrastructure** (chapter 7). Each of these chapters follows the same structure that contains:
  - **Where are we now**: A brief introduction in the major R&D trends and current market maturity for the adoption of EO solutions
  - **Where do we want to be**: A thesis by the FIRE team on the desirable future for EO adoption in each sector based on an amalgamation of insights collected throughout FIRE.
  - **How to get there**: A number of concrete actions following a standardised template that form the practical roadmap proposed by FIRE in each sector.
- Chapter 8 presents cross-cutting actions that transcend the strict borders of each sector.
- Chapter 9 brings together the final conclusions stemming from the development of the roadmap and provides some reflections on potential future work.

Thanks to this structure, the reader may choose to focus only on a given sector or browse through the totality of sectors instead. To further accommodate this, FIRE will produce a series of "extracts" summarising and visualising the main findings for each sector.

2 Marine & Maritime

The marine & maritime sector comprises all activities that are related to the **oceans, seas, and coasts**, except for renewable energy, which is (partially) the focus of the energy section (Section 5 Wind energy). The focus of FIRE is on such marine-based activities as **fisheries and aquaculture**; **marine transport** (including sea-ice navigation); **coastal management**; **offshore assets monitoring**; **marine ecosystems and water quality**.

2.1 Where are we now?

Oceans and their contribution to the sustainability of the life on our planet are increasingly the focus of many international, national, or regional efforts. Major initiatives such as the United Nations **Decade of Ocean Science for Sustainable Development**[1] and the EU's research and innovation mission for 2021-2027 to **Restore our Ocean and Waters by 2030**[2] are focused on this vast area. Indeed, the marine life is a crucial part of our planet's biodiversity, marine products ensuring food security and **growing global food demand** together with the agriculture sector's production. In addition, marine-based activities' current contribution and further potential for our economy is considerable, the EU's blue economy representing roughly 4.5 million direct jobs and generating a gross added value of almost €500 billion a year. Keeping our oceans **clean, healthy, and sustainable** by fighting the over-exploitation of resources or pollution and mitigating ocean warming and its consequences are therefore high on the international agendas. The most important pillar in this effort is the improvement of **marine knowledge**, as scientists point to still important knowledge gaps and limited understanding of this valuable resource and management of the ocean systems in general.

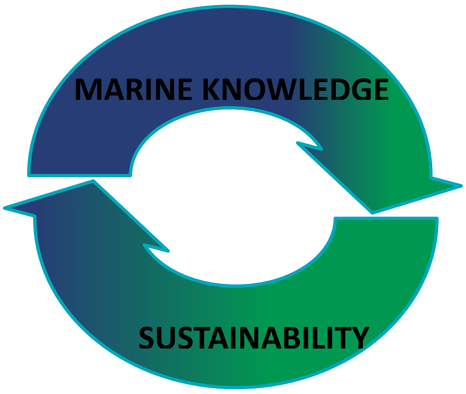


Figure 3: Sustainability and marine knowledge as the interconnected pillars of the R&D in the sector

Strong political momentum at the EU and international level

For the above reasons, **various specific or overarching policies constitute a core driver for R&D** in the marine sector. The European Union holds a prominent place in the international fora and is a leader in the UN initiatives dedicated to the Ocean, but also brings forward an important set of core political frameworks such as the strategy for a Sustainable Blue Economy and Integrated Maritime Policy. The Integrated Maritime Policy represents since 2007 an umbrella framework aiming to establish a more coherent approach to maritime issues through enhanced coordination between different policy areas – Blue Growth, Marine data and knowledge, Maritime Spatial Planning, integrated maritime surveillance, Sea basin strategies, International Ocean Governance.

Adopted in May 2021, the **Blue Economy strategy**[3] is set to ensure the transition from "blue growth" to a "sustainable blue economy", as called by the European Green Deal, while also addressing post-COVID recovery efforts through green and digital transitions in the sector. In addition, marine biodiversity and support to

[1] https://www.oceandecade.org/
[2] https://research-and-innovation.ec.europa.eu/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe/eu-missions-horizon-europe/restore-our-ocean-and-waters_en
[3] https://oceans-and-fisheries.ec.europa.eu/ocean/blue-economy/sustainable-blue-economy_en

conservation efforts are the core to the **Marine Strategy Framework Directive (MSFD)**[4], but also targeted by the **EU Biodiversity Strategy**[5], **Habitats directive**[6] and **Natura 2000**[7].

For fisheries and aquaculture, the Green Deal aims are reflected on the dedicated **European Maritime, Fisheries and Aquaculture Fund (EMFAF)**[8] boosting innovation and investment in sustainable technologies for the blue economy. In addition, the **Common Fisheries Policy (CFP)**[9] is the first comprehensive legal framework setting rules for fishing in the European waters to achieve environmental, economic, and social sustainability of EU fisheries. As for aquaculture, the fastest growing food industry in the world, it has also been integrated into the **EU's Farm to Fork strategy**[10] and is a subject of a targeted strategy crucial to improve both the sustainability and competitiveness of EU in the global aquaculture market.

On top of the European and any national or regional policies, many international standards and efforts at policy-making level are also at play. These include marine-sector specific laws or rules to **combat illegal activities (smuggling, Illegal, unreported, and unregulated fishing (IUU)) at sea** such as the **United Nations Convention on the Law of the Sea (UNCLOS)**[11] or the Food and Agriculture Organisation's (FAO) **Code of Conduct for Responsible Fisheries**[12]. In addition, global action frameworks can also have implications for the marine-related activities, such as the Sendai Framework for Disaster Risk Reduction and United Nations Sustainable Development Goals (e.g. goals of Zero Hunger, Clean Water and Sanitation, Climate Action, or Life Below Water).

Potentially increasing role of EO-enabled solutions

In the previously described context, EO is uniquely positioned as EO-enabled solutions can support many of the marine-related activities. The below SWOT analysis covers the strengths, weakness, opportunities, and threats from the **viewpoint of EO data enabled services adoption by the marine sector**.

Strengths	**Weaknesses**
- Wide (global) coverage bringing a possibility to scale up a solution - Cost-effective compared to in-situ monitoring solutions and various other aerial-based data sources - Transparent, continuous, reliable source of data, including archive information to understand long-term trends and effects - Partially independent of weather and day/night conditions - Monitoring ecological impacts or resource usage over vast geographic regions - Recent upstream advances (e.g. SAR constellations) enable better resolution EO data	- Barriers linked to knowledge, processing capabilities (big data, AI), storage of data - Entry barriers for the integration of actionable information in the existing workflows - Limited spatial resolution (in particular for free data), and significant complexities for use in coastal waters - Need to validate or complement the information with other sources (including in-situ, other arial-based data) - For timely interventions and actions (near)-real time observational capabilities are important (which come with a significant cost)

4 https://research-and-innovation.ec.europa.eu/research-area/environment/oceans-and-seas/eu-marine-strategy-framework-directive_en
5 https://environment.ec.europa.eu/strategy/biodiversity-strategy-2030_en
6 https://ec.europa.eu/environment/nature/legislation/habitatsdirective/index_en.htm
7 https://ec.europa.eu/environment/nature/natura2000/index_en.htm
8 https://oceans-and-fisheries.ec.europa.eu/funding/emfaf_en
9 https://oceans-and-fisheries.ec.europa.eu/policy/common-fisheries-policy-cfp_en
10 https://food.ec.europa.eu/horizontal-topics/farm-fork-strategy_en
11 https://www.un.org/depts/los/convention_agreements/convention_overview_convention.htm
12 https://www.fao.org/iuu-fishing/international-framework/code-of-conduct-for-responsible-fisheries/en/

Opportunities	Threats
- Lack of knowledge and understanding of the marine ecosystems and the anthropogenic effects, including climate change - Pressures related to the need for efficiency (e.g. oil prices) and sustainability (e.g. fish stock fluctuations) of marine operations - Strong regulatory and societal drivers - Growing sector (e.g. aquaculture) - Increased digitalisation of the marine industry (e.g. green shipping) - Improvements of technological capabilities of the enabling infrastructure (deeptech, data analytics, big data, machine learning etc.) - Consumer demands for more transparency and sustainability for food (fisheries & aquaculture)	- EO solutions not adapted to the needs of the end users - Limited incorporation into official and legal workflows - Lack of awareness of the potential of EO - Lack of skilled personnel to use the EO data - Decreasing costs and increased ease-of-use of alternative solutions (e.g. UAVs) - High accuracy of other solutions (e.g. in-situ, cell phones, cameras, UAVs)

Marine challenges for which EO-enabled solutions present strongest value proposition

As highlighted previously, the marine sector faces many challenges with the overarching improvement of marine knowledge and sustainability being central pillars. EO can play an important role for the interconnected knowledge and sustainability, while more specifically bringing value and insights to improve the efficiency of current methods of addressing the following challenges:

- Security (maritime piracy and terrorism, border control)
- Environmental concerns and regulations
- Biodiversity (IUU fishing, pollution)
- Food security and safety (IUU fishing, pollution)
- Traffic (monitoring routes, pollution, oil spills)
- Pandemics and unforeseen global events (impact on many sectors: commerce, tourism, food safety)

2.1.1 Market maturity

When it comes to marine applications enabled by Earth Observation, market maturity varies greatly. Remote sensing is strongly positioned when it comes to marine surveying and mapping, or assisting with the identification, detection and tracking of vessels, but also security at sea related to fishing vessel navigation, monitoring and IUU control. In such cases, applications are expected to either see the growth of the EO role, or the revenues of EO based services would grow together with the sub-sector itself. For instance, EO advancements in observational capabilities bring new deals between public bodies and private companies like in a recent deal for dark vessel tracking between Ursa Space Systems and Spire Global[13].

According to the EUSPA Market report 2022, the total amount of EO data and services for the **maritime sector** for 2021 accumulates to €78 million globally. It is expected that the EO data sales will increase slightly in the next decade, while EO services would double in terms of revenues. While **marine surveying and mapping** has reached its maturity and is not expected to go through a considerable growth, applications such as **ship route optimisation**,

[13] Deal for tracking dark vessels with synthetic aperture radar (SAR) imagery (Ursa Space) and radio frequency (RF) monitoring satellites (Spire): https://www.satellitetoday.com/government-military/2022/08/17/ursa-space-spire-partner-on-maritime-domain-awareness-services-for-government/

navigation through sea ice, port security, maritime pollution monitoring or **Metocean** are forecasted to double in size before 2031.

For **fisheries and aquaculture**, the annual revenue from the sale of both EO data and services to the fisheries sector is estimated to grow from €54 m in 2021 to €92 m in 2031. **Fish stock detection** and **Illegal, unreported, and unregulated (IUU) fishing control** hold almost equal shares throughout the projected timeframe. The structure of the total revenue for each of the two applications is, however, very different. For Fish stock detection revenues from services make up to 97% of the total by 2031. On the other hand, IUU fishing control revenues will comprise in 2031 of 67% in services and 33% in data sales. The market for EO data for **aquaculture** activities is currently in its infancy. Nonetheless, given the importance aquaculture has gained in recent key policies as well as the overall growth of the market, one can expect that in the very near future such revenues will become substantial.

2.1.2 R&D trends

There is a set of R&D trends for the marine sector which either develop and enhance marine knowledge and/or improve the sustainability or efficiency of ocean-related activities:

- Current research sets out to improve the **understanding of the marine environment** in all its facets, including extreme and special environments, such as the Arctic (**Arctic+Salinity**) or Antarctic ice-sheet and its role within broader ice sheet and ocean systems (**4DANTARCTICA**). Related to these efforts, but going beyond and above are the efforts of **Building a Digital Twin of the Ocean** (H2020 ILIAD and Mercator Ocean Digital Twin Ocean) or a more targeted project developing marine modelling tools for the next generation systems of the Copernicus Marine Environment Monitoring Service (IMMERSE).
- **Marine coastal areas** are also a research priority of multiple projects, but also one of the highlights of the Copernicus Marine Environment Monitoring Service (CMEMS) development trends. Mapping **coastal bathymetry** via the ESA-supported **BathySent** project and EO4SD action, **coastal water quality** monitoring (**CoastObs**, **EOMORES**) or high resolution water quality and met-ocean indicators in coastal and nearshore areas (**FORCOAST**).
- **Water quality measurements** are still improved beyond the more particular coastal areas with applications proposing to combine oceans, lakes and transitional waters in their offering (**CERTO**) or focusing on the resolution of the water quality data at sea (**HiSea**).
- Other projects focus on **marine pollution** by developing a platform for real-time management of marine pollution events in the wider area of EU harbours and their vicinities (**IMPRESSIVE**) or forecasts of macro litter drift (**C-TEP**). Ongoing research is also setting out to enhance the scientific understanding of marine debris transport, tracking of **oil spills** and **accumulation of plastic** in the sea (STUOD).
- R&D efforts are also aimed at enabling **sustainable fisheries or aquaculture management** with emphasis on maintaining healthy marine ecosystems (EcoScope), or ecolabelling, impact assessment and commercialisation (NextOcean - Next Generation of Fishing and Aquaculture Services). Similarly, monitoring the growth rate and water parameters for shellfish is the focus of a pilot project Rheticus AquaculturePlus.
- Other R&D efforts in EO are aimed at **expanding the use of EO in the marine sector**: recent research[14] highlights use of **EO for environmental and social impact assessment of aquafarms** by translating the EO-based analyses of land cover changes to the seascape.

Current R&D also emphasize the integration of EO interaction with other (emerging) technologies and data streams:

- **EO integration with in-situ** information for improved **water quality** (**EOMORES**).

[14] Remote Sensing for Aquaculture: https://www.frontiersin.org/articles/10.3389/fmars.2020.638156/full

- Combining EO with other **technological advancements to improve marine observations** (NAUTILOS) by involving new users, but also aiming at open-source and products produced to enable further knowledge transfer.
- Development of increasingly complex but user-friendly combinations of satellite remote sensing capabilities with **advanced analytical techniques, Internet-of-Things and other ICT** solutions. For instance, **traceability** improvements are explored and demonstrated through projects such as AquaLedger where the value of EO is combined with **blockchain** and **Distributed Ledger Technology (DLT)** for supply chain management in fisheries and aquaculture.
- While iFishIENCi, a Horizon 2020 project, aims to **improve fish feeding** by combining **digital monitoring**, **artificial intelligence**, **Internet of Things** and other technological advances with EO and GNSS.

2.2 Where do we want to be?

The following subsections take stock of the discussion presented in "where are we now" and highlight the main directions in which the development of EO solutions, as well as adoption thereof, for marine applications can go to.

2.2.1 Comprehensive use of EO for ocean health assessment, monitoring and modelling

One of the most complex and challenging tasks on which all other goals of the sector depend on at least to some extent is the improvement of our understanding of the marine environment to manage the resource in a more sustainable way. EO is a rich tool which can assess crucial seas and ocean parameters such as salinity, temperature, waves, currents, nutrients etc. Together with a variety of in-situ data for calibration and validation, EO helps characterising the ocean's current state and model its short, mid-term and long-term evolution.

There are multiple priority areas where more or better EO data can bring significant added value. These can be categorised in **geographical and/or thematic priorities**. Among geographical priorities is a better use of EO data in certain more complex environments such as the coastal areas or the Arctic. For instance, the extension of the CMEMS service to coastal areas is a current priority (2021-2027) which will be achieved by building a system of systems and combining input from Copernicus Marine, Land, Emergency and Climate services. An example from a thematic priority is improving our understanding of the ocean's pollution and its impacts on the ocean's health (BlueMed SRIA). Similarly, oil spills, eutrophication, sargassum, water quality and biodiversity will all remain crucial thematic areas of EO-enabled further exploration achieved through a better quality and quantity of ocean data inputs. To work towards this improved understanding and operations, the Group on Earth Observations (GEO) has 7 thematic areas, 4 led by the EU – marine litter, fisheries, sargassum and coastline changes.

What is needed for both short, mid-term and long-term, is **combining the information with modelling and planning**. Activities such as the **Maritime Spatial Planning** is where EO data should play an important role. However, often the MSP activities are at a local scale while marine biodiversity is clearly a global issue. Therefore, building the **Digital Twin** of the ocean is one of the most important and ambitious goals enabling global mid-term and long-term planning and testing. Working towards an operational Digital Twin of the Ocean is one of the international priorities as such a system of systems can contribute not only to climate change adaptation for all marine sectors, but it can also guide all marine activities in the future.

2.2.2 More EO in well-established domains

As discussed in chapter 2.1.1 on Market maturity, the use of EO is expected to increase in most of the marine sub-segments.

For uses such as the **management of the production of marine living organisms and IUU control support** there is still room for **more widespread uptake** by both authorities and fishermen or aquafarmers, especially in the smallholder fisheries and the fast-growing and increasingly digitalised aquaculture sectors. In addition, **further improvements for operations and monitoring** of fish stock and aquaculture are needed to address global pressure on decreasing fishing fleets and increasing efficiency while improving sustainability. Products targeting small scale and closer-to-shore or inland water fishing and aquaculture, as well as general improvements of data quality, reliability, time-series (real-time information) of ocean variables such as temperature could help both industries, but also authorities and research bodies.

For ice navigation and **sea ice information** for other purposes, including climate change, increased access to **Synthetic Aperture Radar (SAR)** imagery brings great potential which still needs to be fully exploited. CMEMS' strategy highlights the promise in multisensor (altimeter, Pressure-modulated Radiometer, Visible Satellite Imagery and Infrared Imagery) approaches to increase the robustness of automatic analysis, observations and forecasts. Here the improvements of the service are also user-driven as CMEMS highlights increasing demand for high spatial and temporal resolution of this information.

We have illustrated above some drivers for the need of further EO uptake in the marine and maritime sector. Similarly, both the advances in EO technology and the underlying infrastructure are also enabling improved navigation and marine surveying and mapping.

2.2.3 Balancing between efficiency and scalability of EO-powered solutions

A commonly emphasized advantage of EO as a data source is the availability of global data, therefore, a possibility to scale up an EO-based solution for use by various customers around the globe. However, consultations of users as part of the FIRE project have yet again highlighted the need to tailor EO-based solutions to the needs of the users, which implies that particular needs are taken into account and a solution is customized to these needs. In other words, fit-for-purpose solutions are still in high-demand.

This is where the full technological and digital advances need to be adopted by EO solution providers to create solutions which are both scalable and customizable. Scalability can be further improved through the use of cloud capabilities (access, storage, processing), while smart algorithms (AI, machine learning) are crucial for enabling customisation. Other examples helping to improve EO-based solutions' uptake include involvement of users in the design process via co-design and/or user-friendly interfaces.

2.2.4 Full competence of EO use among marine and maritime professionals

Further work needs to be done to reach full competence of the sector when it comes to using EO data as part of the workflow of marine and maritime professionals. While many solutions have been established, the lack of technical capabilities to work with geospatial data and the difficulty to understand the data are important barriers for a more widespread adoption of EO-based solutions. This is more acute for smaller actors such as smallholder fishermen or aquafarmers, local authorities, but also bigger actors, research and governmental bodies could further benefit from efficiency improvements and workflow-fit of EO-based solutions.

2.2.5 EO adoption in support of global societal goals and political priorities

In Chapter 2.1 we have highlighted the strong political momentum of the marine and maritime sector at the EU and international levels. EO's role in enhancing sustainability, food security, environmental goals and the SDGs related to the marine sector should become unequivocal. CMEMS is already responding to monitoring and assessment needs required by international policies, frameworks and agencies (e.g. Intergovernmental Panel on Climate Change, Sendai Framework for Disaster Risk Reduction, UN Decade for Ocean Science for sustainable development etc.). However, further legislative work could help establishing the use of EO at all levels of governance. EO data could further support the fight against illegal activities at sea, but also improve traceability and certification of, for instance, wild fisheries catch. Indeed, EO together with other technology and data processing capabilities (GNSS, IoT, blockchain, machine learning) can improve transparency and traceability «catch to plate» requested by the consumers.

2.3 How to get there?

To reach the desired developments discussed previously a number of actions can be pursued.

2.3.1 Action MAR 1: Integrated systems support

Action number: MAR_1	**Timeframe**
Description There is a need to **continue support for the development of integrated systems of systems for marine life monitoring and modelling**, relying on EO-based solutions and contributing to a better understanding of the marine environment. This effort would require financial, technical and advisory support for actors developing applications that combine a system of systems approach with demonstrated end-user considerations.	Short-term (1 – 2 years) **Mid-term (2 – 5 years)**

How

This action entails a number of steps.

- **Comprehensive evaluation of current user needs and technical developments** which could address these needs. This is important as there are many existing solutions which require further adjustments to ensure workflow/user need fit.
- Roll out of European, national or regional **R&D funds** dedicated to **applications integrating and combining in-situ and EO data streams and making them available through an accessible and user-friendly interface to the end user**. Additionally, these systems of systems should demonstrate the use of efficient yet adaptable algorithms and/or the latest ICT developments (data mining, analysis of "big data", machine learning, blockchain etc.) and/or involve users in the development of such solutions via co-design strategies.
- **Advisory support** for commercialisation of the developed applications and/or scaling them up for the broader use.

Who

- Marine knowledge centres and coordination – EU4OceanObs, GEO Blue Planet, GEOBON, MBON, GOOS
- DG MARE (inc. Ocean Observation Initiative), DG CNECT, DG DEFIS, JRC
- EMODnet, CMEMS, but also other relevant Copernicus Services (C3S, CLMS)
- End users (marine industry professionals, authorities, research institutions etc.)
- EO service providers
- EUSPA fostering market development advisory efforts

Impact

- Improved understanding of the marine life for more sustainable management of the resource and adaptation for future challenges
- User-friendly and actionable tool(s) for observing and analysing the state of the marine life
- Better use of existing resources (EO data, achieved progress)
- More widespread uptake of EO-enabled solutions

Impact on	Low	Medium	High
end users			**High**
EO service providers			**High**
multipliers		**Medium**	
governance actors		**Medium**	

2.3.2 Action MAR 2: Fostering marine data availability and accessibility

Action number: MAR_2

Timeframe

Short-term 1 – 2 years | Mid-term 2 – 5 years

Description

Marine ecosystems as a shared global resource can best serve both businesses and the society if **marine data is made available to the largest possible user groups**. R&D actions stimulating creation of open-source data, data sharing and improving in-situ data availability would help achieving many of the marine sector goals, from small-scale and local to the most ambitious goals of an efficient Digital Twin of the ocean.

How

- Launch of **R&D actions providing open-source marine data** (notably in-situ data), data sharing systems and/or APIs as part of the project results
- Fostering **innovative data production**, mining, or gathering strategies such as crowdsourcing or data crawling, machine learning, deep learning
- Further **R&D of hyperspectral for marine applications**, specifically for water quality
- Development of the use of cloud and capacity building when necessary
- Standardisation of initiatives to achieve the highest level of interoperability of pre-processed data

Who

- Universities, Research Institutes, Scientific bodies, Innovation centres, EO service providers, Copernicus Services etc. in the frontline of the R&D efforts of providing more accessible and available data
- EU4OceanObs, GEO Blue Planet could help fostering standardisation and exchange of best practices
- DG MARE (inc. Ocean Observation Initiative), DG CNECT, DG DEFIS, DG AGRI, JRC supporting efforts through e.g. Horizon Europe working programmes
- EMODnet, CMEMS, but also other relevant Copernicus Services (C3S, CLMS)

Impact

- Better quality and improved availability of marine data (both EO and in-situ)
- New or improved EO-based solutions that leverage cutting edge technological approaches
- Improved preparedness for future challenges (climate change mitigation, modelling of long-term scenarios etc.)
- Involvement and engagement of citizens and other actors in the work for improved marine sustainability

Impact on	Low	Medium	High
Impact on **end users**			**High**
Impact on **EO service providers**			**High**
Impact on **multipliers**		**Medium**	
Impact on **governance actors**		**Medium**	

2.3.3 Action MAR 3: Incorporation of EO in key policies and strategies

Action number: MAR_3

Timeframe

Short-term 1 – 2 years | Mid-term 2 – 5 years

Description

Incorporation of EO solutions in key marine and maritime policies and strategies, would create a regulatory framework that dictates EO use and allows the realisation of association benefits across multiple applications.

How

This action entails several important steps. The first concerns a thorough **review of current provisions for EO use in relevant policies** including a detailed account of the precise use cases and associated user needs that EO seeks to support in such cases. This could benefit from recent work by JRC in studying the use of Copernicus data in support of EC DGs as well as relevant sectorial fora (e.g. on bathymetry).

Then, ideally following **expert consultation** (with researchers and industry sharing their voice), a **concerted effort to incorporate EO solutions in relevant policies and strategies** at national, regional, European, or global level should be undertaken. This could build on similar efforts for agriculture, water management and forestry and focus on areas such as the Common Fisheries Policy, other policies related to the protection and restoration of marine environment, Marine Spatial Planning etc.

Finally, this action should entail **focussed efforts to advocate for the use of EO in regional and national planning** and policy documents both to raise awareness, but also enable more widespread uptake of EO-based solutions by authorities. The latter could be further supported by **innovation procurement schemes** (e.g. PCP) supported by Horizon Europe or national funds (following lessons learned from e.g. Marine-EO).

Who

- DG MARE (inc. Ocean Observation Initiative), DG AGRI, DG DEFIS, JRC
- Relevant European agencies – EMSA, EFCA
- International and European bodies – EU4OceanObs, GEO Blue Planet
- EARSC
- Regional and national authorities

Impact

- Amendments of EU, national or regional policies to incorporate (or update the references to) EO solutions
- Increased uptake of EO data in policy making and implementation/monitoring of regulation
- Economic, environmental and other benefits for governmental authorities responsible for implementing policies at EU, national and regional level

Impact on **end users**: Low | **Medium** | High

Impact on **EO service providers**: Low | Medium | **High**

Impact on **multipliers**: Low | Medium | **High**

Impact on **governance actors**: Low | Medium | **High**

2.3.4 Action MAR 4: Demonstrating the value of mature EO applications

Action number: MAR_4

Timeframe

Short-term 1 – 2 years | **Mid-term** 2 – 5 years

Description

As described in earlier chapters, several marine applications are advanced users of EO solutions or are in good position to become so. In such cases, the key is to further demonstrate the value of EO solutions, clearly highlighting (in a quantifiable manner) the generated benefits. This, together with the promotion of champions and success stories, can serve as an essential push for widespread adoption among marine and maritime professionals, especially when coupled with R&D developments that take into account evolving needs and realities.

How

This action has two strands. The first concerns **awareness raising activities**. These may include the following:

- Meeting the **marine professionals at their events** (involving sectoral "ambassadors" enthusiastic and knowledgeable about EO through programmes such as the "EO Evangelist" programme of the FIRE project); **organisation of targeted workshops and matchmaking events**
- Dedicated studies **showcasing the benefits generated across different applications for different value chains actors by EO solutions;** organising **campaigns promoting success stories and champion users**

The second strand, tightly connected to the first one involves **innovation support actions**.

- Targeted **hackathons or acceleration programmes** with cross-sectoral teams, bringing around the table EO and marine professionals
- Innovation actions for **improving specific existing service applications** (e.g. ship route optimisation, bathymetry) and improve user uptake of mature EO applications, with the advancements exhibited in well-defined **demonstrators involving relevant users**.

Who

- DG DEFIS, EUSPA, DG RTD
- EMODnet, CMEMS, but also other relevant Copernicus Services (C3S, CLMS)
- End users (marine industry professionals, authorities, research institutions etc.)
- EO service providers

Impact

- Increased uptake of EO in mature application areas, documented by quantifiable market growth
- Improved EO services targeted to user needs and delivered both by established actors and start-ups, SMEs

Impact on	Low	Medium	High
Impact on **end users**	Low	Medium	**High**
Impact on **EO service providers**	Low	Medium	**High**
Impact on **multipliers**	Low	**Medium**	High
Impact on **governance actors**	Low	**Medium**	High

2.3.5 Action MAR 5: Support for thematic priorities in underdeveloped R&D areas

Action number: MAR_5

Timeframe

Short-term
1 – 2 years

Mid-term
2 – 5 years

Description

Support for the development of scalable tools for targeted underrepresented sub-sectors or problems. This would result into financial, technical, advisory support for actors developing applications which bridge the gap in the current offer. For instance, applications targeting particular complex topics or areas such as coastal waters or underrepresented user groups such as smallholder fishermen, or both when targeting marine spatial planning and authorities.

How

- Analysis of the current application evolution and gaps in terms of groups of users not yet targeted and/or technological advancements impact and/or thematical priority areas
- Research and Innovation Actions supporting the development of dedicated applications targeting smaller fisheries and designing both the technological support as well as a package of the right incentives for the use of accessible digital reporting systems which would be integrated with monitoring and planning tools.
- Research and Innovation Actions for applications in marine coastal waters leveraging on satellite data, including hyperspectral potential and other new technological developments.
- Innovation Actions for the development of marine spatial planning assistance for authorities to help the achievement of both national goals and EU priorities, as well as the overall sustainability and coherence of marine governance

Who

- DG DEFIS, EUSPA, DG RTD
- EMODnet, CMEMS, but also other relevant Copernicus Services (C3S, CLMS)
- End users (marine industry professionals, authorities, research institutions etc.)
- EO service providers

Impact

- New EO solutions supporting underrepresented communities
- Scientific and technological advancements tackling identified gaps
- Improved marine governance and resource use efficiency

Impact on	Low	Medium	High
Impact on **end users**	Low	Medium	**High**
Impact on **EO service providers**	Low	Medium	**High**
Impact on **multipliers**	Low	**Medium**	High
Impact on **governance actors**	Low	Medium	**High**

2.3.6 Action MAR 6: Capacity building

<table>
<tr><td>Action number: MAR_6</td><td rowspan="2">Timeframe

Short-term
1 – 2 years
Mid-term
2 – 5 years</td></tr>
<tr><td>Description

Essentially all the previous actions for the Marine Sector can benefit from targeted capacity building activities. These should be focussed on training marine professionals, authorities and other non-expert groups in the use of EO-based solutions in their operational workflows.</td></tr>
<tr><td colspan="2">How

Launching a comprehensive capacity building programme that leverages best practices and successful training tools to enable practitioners in making the most of EO-based solutions. This programme could be supported by a collaboration between relevant entities (e.g. EUSPA, DG MARE, Mercator Ocean) and entail the following:
Thematic workshops and trainings targeted to the particular group (e.g. public authority or marine professional). These trainings should also put strong focus on co-design practices benefitting from relevant results in key projects (e.g. e-shape).
Developing collaborative spaces where partnerships between the industry, universities and users can be forged (along the triple helix logic) so that they share knowledge of efficient processes and best practices (e.g. use of cloud) for efficient and scalable building of EO applications</td></tr>
<tr><td colspan="2">Who
Marine industry professionals and national, regional authorities as potential beneficiaries
Copernicus Academy, EO service providers, Copernicus Services, EMODnet as well as governing bodies and EU agencies (DG MARE, DG RTD, JRC, DG DEFIS, EUSPA) as partners or organisers of the capacity building activities</td></tr>
<tr><td>Impact
Stimulating a shift towards user-driven design of EO solutions Facilitating the integration of EO solutions in the workflow of the marine industry Growing awareness and understanding of the EO potential</td><td>Impact on end users: Low | Medium | High
Impact on EO service providers: Low | Medium | High
Impact on multipliers: Low | Medium | High
Impact on governance actors: Low | Medium | High</td></tr>
</table>

3 Urban Development

Increasing urbanisation entails various challenges for aspects such as mobility, air quality, critical infrastructure, security, poverty, health, or housing. Urban Development in this context refers to the design and operation of urban spaces by means of planning, construction, and maintenance. Earth Observation (EO) can facilitate the planning, monitoring, and management of urban environments and contribute to more liveable and more sustainable cities.

3.1 Where are we know?

To date, about 75%[15] of the European Union's population lives in urban areas and 68%[16] of the world's population is projected to do so by 2050. More than 80%[17] of the global GDP is generated in cities, making their functioning crucial for the global economy. At the same time, these constantly growing areas are largely contributing to the consumption of resources and pollution of the environment while themselves exposed to increasing risks associated with e.g. urban sprawl, climate change and natural disasters, or pandemics. Municipalities are challenged with maintaining services, providing smart mobility, minimising environmental degradation, and the need to ensure the health and wellbeing of their citizens while reducing social inequality. This requires well-informed planning, development, and efficient and sustainable operations of urban areas. City planners and municipalities require solutions to monitor assets and conditions and to anticipate future developments and impacts. EO solutions could provide the required data and information for monitoring, decision-making, or policy-enforcement.

The following policies and initiatives describe some of the key drivers for information needs in Urban Development, enabling the required monitoring, decision-making, and policy-enforcement activities.

Policy / Initiative	**Description**
United Nations Sustainable Development Goals (SDGs)	• **SDG3: Good Health and Well-being:** living conditions in urban areas, including e.g. air quality or availability of green spaces, have a significant impact on citizens' health and well-being • **SDG11: Sustainable cities and communities:** access to public transport, open spaces, and quality of air are some of the crucial factors for quality of life and environmental sustainability in urban areas
OECD Principles on Urban Policy	• Aiming at adaptation of a coherent, integrated, and effective strategy to build smart, sustainable, and inclusive cities • Co-developed with international organisations, development banks, networks of cities and local governments, research institutes and academia, and private sector actors • Implementation supported through the Athens Pledge
Regional Development and Cohesion Policy 2021-2027	• Supports locally led development strategies and sustainable urban development across the EU • 6% of the European Regional Development Fund is dedicated to sustainable urban development

15 https://data.worldbank.org/indicator/SP.URB.TOTL.IN.ZS?locations=EU
16 https://www.un.org/development/desa/en/news/population/2018-revision-of-world-urbanization-prospects.html
17 https://www.worldbank.org/en/topic/urbandevelopment/overview

Policy / Initiative	Description
	• The new European Urban Initiative further supports the urban dimension as a new networking and capacity-building programme for urban authorities
Urban agenda for the EU[18]	• Supports development of action plans (e.g. on legislation, funding programmes, best practice sharing) through partnerships between the Commission, EU organisations, national governments, local authorities, and NGOs • Priority themes include air quality, circular economy, climate adaptation, culture and heritage, digital transition, energy transition, housing, inclusion, public procurement jobs and skills, sustainable use of land and nature-based solutions, urban mobility, and poverty

The SWOT analysis below covers the strengths, weaknesses, opportunities, and threats from the viewpoint of EO data-enabled services adoption by Urban Development actors and stakeholders.

Strengths	**Weaknesses**
- EO data available for all land cover including urban areas in Europe - Different sensors already today enable monitoring solutions in a wide range of application fields relevant in an urban context - Cost-effective monitoring compared to regular on-site inspections	- Low resolution (for free Copernicus data), insufficient for several desirable applications - No one-fits-all solutions directly applicable to any city exist - Not integrated in existing workflows at most municipalities
Opportunities	**Threats**
- Policy enforcement required by cities in areas where EO data specifically can contribute to the required monitoring - Affinity for geospatial and environmental data among city planners, where currently used sources can be augmented with better or complementing EO data	- Lack of awareness about availability and capability of EO data and information - Lack of required skills among targeted end-users such as city planners, public authorities, and other actors - Procurement processes not always ready to explicitly include EO information and data

Some of the overarching challenges facing the Urban Development sector include:

- **Growing population** in urban areas
- **Climate change** affecting urban **resilience** and **health** of citizens
- Increasing **digitalisation** as a requirement for a transition towards smart cities
- Functioning **urban mobility** providing efficient, affordable, and sustainable access to transportation

3.1.1 Market maturity

[18] https://ec.europa.eu/regional_policy/en/policy/themes/urban-development/agenda/

Revenues from EO data and services[19] sales in 2020 exceeded €300m, with 45% of that attributed to applications in surveying and mapping of urban areas. This application field is also projected to grow most during the next 10 years, with other fields such as urban planning, modelling, monitoring of informal dwellings, air quality monitoring, or urban heat islands projected to experience moderate growth. Overall, revenues are expected to exceed €760m by 2031.

Many of these applications are in areas crucial to achieving goals linked to urban challenges and policies. Urban green infrastructure can be utilised to counter urban heat, which is a growing threat. Climate neutrality can only be achieved with cities taking the leading role in climate-related actions. Thus, EO may play a bigger role soon also to observe compliance with these policies and to assess the impact of measures. However, there are currently no turnkey solutions that work for all municipalities without customisation and integration efforts. While some free data exists, it will still require dedicated processing and analysis. For some applications, resolution and / or revisit times of satellites providing free data may not be sufficient, requiring acquisition of costly commercial data. This constitutes an additional barrier to the uptake of EO among urban planners. But given the increasing urgency of challenges to be tackled, EO solutions may become more cost-effective per se with their constantly evolving capabilities (larger constellations, higher revisit times, higher resolution, wider types of sensors and data) adding to their attractiveness and usefulness in urban contexts.

3.1.2 R&D trends

Urban challenges are met by numerous research initiatives aiming to tackle these, many of which are including EO data in their approaches or even centring it around EO. ESA's Earth Observation for Sustainable Development (EO4SD) initiative for example aims to increase EO uptake in a wide field of sectors, with EO4SD-Urban (2016-2019) aiming to derive key geo-information products from Earth Observation data in support of urban development programmes. Aspects included e.g. **land valuation**, **organisation of urban spaces**, interventions in **informal settlements**, **inclusion**, municipal spatial **data infrastructures**, planning for **public transport** infrastructure, **water supply** and **sewage**, **environmental sustainability**, **flood risk** assessment, or **climate change**. Environmental challenges are a major focus for and have been addressed by projects like SMURBS (2017-2020), which aimed to increase urban resilience targeting challenges with respect to **air quality**, **urban growth**, natural/manmade **disasters** and relevant impacts and more entangled issues such as the **migrant crisis** and the **health** implications of such environmental pressures via means of EO. Other research on **urban resilience** is done by projects such as CURE (2020-2022), which is developing cross-cutting applications among Copernicus Core Services to address urban resilience, coping with the required scale through the exploitation of third-party data, in-situ observations and modelling. And Harmonia (2021-2025) is developing a support system based on satellite and auxiliary data for improved resilience and sustainable urban areas to cope with climate change and extreme events.

A lot of research also goes into the topic of **data fusion**, where data from various sources are combined to create a holistic picture. The So2Sat project (2017-2023) for instance fuses remote sensing data from diverse sensors, including EO satellites with massive data from GIS and social media to map 3D urban infrastructures and their evolution over time. LandSense (2016-2020) aggregated EO technologies, mobile devices, community-based environmental monitoring, data collection, interpretation, and information delivery systems to **empower citizens** to monitor and report on their **environment**. To cope with the large amount of data and to make sense out of it, different initiatives focus on applying **Artificial Intelligence** (AI) to the data. AI4SmartCities (2021-2023) for example generates professional solutions for very high resolution geospatial and social-economic indicators for smart city planning and management by extending AI algorithms and big EO data management properties to very high-resolution data.

All in all, the exploitation of EO data for urban application is at the core of many research initiatives for a wide range of challenges. These indicate a raise of awareness among urban stakeholders in need for solutions.

[19] EUSPA EO and GNSS Market Report 2022, https://www.euspa.europa.eu/2022-market-report

3.2 Where do we want to be?

With a plethora of EO satellites already in orbit, their capabilities (sensors, revisit times, resolution etc.) already now allow for the development and implementation of applications with the potential to be widely used by urban development actors in the very near future. The opportunities stemming from these capabilities paired with the pressing needs across the sector guide the desired solutions within short- and mid-term and the required developments to meet requirements.

3.2.1 EO for Urban resilience in the light of climate change

Cities are increasingly facing extreme weather events and natural disasters linked to their own layouts and environmental impacts as well as global trends of changing climate. This affects a growing population living in vulnerable areas. A state of resilience is desired, enabling actors in urban development to prepare against disasters (e.g. floods) and extreme events (e.g. heat), assess the risks and impact of such events, respond to these with immediate measures, and prevent or mitigate them through better urban planning with the support of EO-enabled solutions.

3.2.2 EO for Smart Cities

Digitalisation is paving the way for smarter cities that mitigate challenges associated with growing populations to remain liveable spaces with efficient and sustainable services, adapting to the needs of diverse inhabitants, and securing their wealth, health, and wellbeing. Among others, this requires technological innovation evolving around data, the connectivity of a large amount of data sources, and the analysis and exploitation of such data for efficient and sustainable planning and operations on the level of buildings, neighbourhoods, and large-scale urban areas and their underlying infrastructure. A wider adoption of EO data can support mapping and simulation of complex systems such as cities and monitoring their performance, providing much of the information required to make cities smarter.

3.2.3 EO for Green cities

With cities in focus of initiatives such as the EU Green Deal aiming at reduction of greenhouse gases and other direct and indirect negative environmental impacts of human activities, cities themselves need to become “greener”. This is literal, with green spaces mitigating challenges such as heat, air quality, and general quality of life. And in the broader sense, becoming environmentally sustainable in their use of land, resources, and emissions. Urban planners must be enabled (with the help of EO) to design sustainable urban spaces and infrastructure and to monitor both the health of its green spaces as well es the performance of its assets, enabling timely intervention where needed.

3.2.4 EO in support of controlled growth

Urbanisation and growing urban populations require space for housing and infrastructure. Urban planners need to remain in control of how settlements evolve, avoiding uncontrolled “urban sprawl” with negative impact on environment, quality of life, and the overall efficiency and performance of cities. EO can support the monitoring of changes in land use, detecting illegal structures as well as features that require enforcement of law, regulation, or taxation. Proper planning must anticipate future demand while constant monitoring supports regulation of urban development. EO does provide rich data that can be further exploited for such purposes.

3.2.5 Urban stakeholders empowered by EO data

Urban development has a variety of stakeholders interested in information regarding local conditions. Urban planners and authorities need a basis for better-informed decision-making, planning, or emergency response. Businesses (including construction companies, real estate agencies, but also service providers, retail etc.) need to analyse and navigate their local environment for optimised offerings and performance aligned with demand and general conditions. And citizens require an environment with efficient services and infrastructure where they are always able to know conditions (e.g. traffic, air quality) and potential threats (e.g. pollution, weather, disasters, upcoming maintenance works) coming from these. EO data must empower these stakeholders, contributing to their inclusion in the design and use of their environment.

3.3 How to get there?

Cities are in focus of many actions targeting sustainability, wellbeing, and wealth. Capacity building is required to guide the evolution of the sector enabled by Earth Observation solutions. Several European initiatives are already driving this through funded actions:

EuroGEO has set up Action Groups with themes including urban, land use and coverage, disaster resilience, climate, and other. These aim to develop new applications for better informed decision making also in urban management.

Two of the five EU Missions in Horizon Europe[20] relate directly to urban development: (i) Adaptation to Climate Change[21] supports at least 150 European regions and communities to become climate resilient by 2030, fostering the development of innovative solutions to adapt to climate change and encourage regions, cities and communities to lead the societal transformation. (ii) 100 Climate-Neutral and Smart Cities by 2030[22] aims to deliver 100 climate-neutral and smart cities by 2030 and all European cities to follow suit by 2050. Funded actions cover subjects such as urban planning and design for climate-neutral cities, sustainable urban mobility, or positive and clean energy districts. With the 100 cities already chosen, these now are in need for Pilots. The Mission platform is currently managed by project https://netzerocities.eu/.

Cities are aware of their role and now need to be enabled to meet the targets set by e.g. the EU Green Deal or Sustainable Development Goals. This requires frequently updated data and information on land use, emissions and air quality, emergency risks and events, as well as the structural health and performance of urban infrastructure. While quality of data needs to improve in some areas, solutions are also required to integrate the various data sources (i.e. satellites, in situ sensors) and to process the data ready for analysis or action at a local level.

In view of all this, the following actions are proposed to leverage and enhance existing EO capabilities in the short- and mid-term to the benefit of urban development and management.

---

20 https://research-and-innovation.ec.europa.eu/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe/eu-missions-horizon-europe_en

21 https://research-and-innovation.ec.europa.eu/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe/eu-missions-horizon-europe/adaptation-climate-change_en

22 https://research-and-innovation.ec.europa.eu/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe/eu-missions-horizon-europe/climate-neutral-and-smart-cities_en

3.3.1 Action URBAN 1: Interfaces for analysis-ready EO data and information

Action number: URBAN_1	**Timeframe** Short-term 1 – 2 years **Mid-term** 2 – 5 years
Description While end users in urban applications may have a certain level of expertise in analysing EO data, that expertise may not suffice to extract and process raw EO data coming from e.g. satellites to a state where it can be used by non-experts. Instead, more analysis-ready data is required, with service providers pre-processing data and making it available in interoperable formats ready to integrate into the information systems and workflows of urban stakeholders.	
How • Marketplaces or platforms specifically for data supporting urban applications need to be in place to enable urban stakeholders to access, procure and integrate data into their processes and systems • Standardisation initiatives are required to ensure interoperability of pre-processed data made available through such platforms, including standardised interfaces between platforms and user applications	
Who • **EUSPA:** market officers responsible for their Urban Development segment should contribute to interactions; specific calls could be launched also through Horizon Europe Work Programmes; funds to support standardisation and platform development could be provided • **ESA:** bringing in their expertise and existing resources stemming from their Urban TEP and EO4SD-URBAN initiatives • **City initiatives:** initiatives (e.g. Covenant of Mayors, Eurocities) representing a large number of diverse cities to bring in their requirements and co-design solutions • **INSPIRE:** representatives of the initiative should contribute to standardisation efforts	
Impact • Increased uptake of EO use among urban stakeholders • Increased business opportunities for EO data and EO service providers • Better enforcement of key policies linked to e.g. environment, climate change, health to the benefit of citizens	Impact on **end users**: Low / Medium / **High** Impact on **EO service providers**: Low / Medium / **High** Impact on **multipliers**: Low / **Medium** / High Impact on **governance actors**: Low / **Medium** / High

3.3.2 Action URBAN 2: EO data integration with Building Information Modelling tools

Action number: URBAN_2

Timeframe

Short-term 1 – 2 years | Mid-term 2 – 5 years

Description

Building information models are digital representations of physical places and their characteristics. Building Information Modeling (BIM) potentially enables cost savigs, efficiency gains, and improved quality and environmental performance of the built environment. Already common practice in the private sector, initiatives such as the BIM Handbook are encouraging the wider use of BIM also in the public sector, which is increasingly becoming mandatory. Integrating EO data in the tools that generate and manage digital building models would benefit the accuracy and detail degree of these and in return support the uptake of EO use.

How

- Data formats for required variables to model buildings require standardisation to ensure wide adoption
- Technical (application) interfaces between BIM tools and data platforms through which the respective data is made available are required
- Providers of EO data and services are required to provide sufficient pre-processed data covering land use, atmosphere, and climate globally and frequently

Who

- **EUSPA**: A designated market officer for urban development should be responsible for driving wider integration of EO into and use of it via BIM tools
- **Software developers**: Major developers of BIM tools need to be able to access and integrate EO data and embrace this data
- **DG GROW and DG MOVE**: The units responsible for construction and transport networks shall be involved in defining required variables and models, extending existing (also funded) efforts of digitalisation for buildings and construction

Impact

- Increased use of EO through application integration
- Improved performance and sustainability of buildings and building maintenance
- Efficiency gains and cost savings in plannning and construction of buildings

Impact on	Low	Medium	High
Impact on **end users**			**High**
Impact on **EO service providers**			**High**
Impact on **multipliers**		**Medium**	
Impact on **governance actors**		**Medium**	

3.3.3 Action URBAN 3: In situ integration

Action number: URBAN_3

Timeframe

Short-term 1 – 2 years

Mid-term 2 – 5 years

Description

In an urban context, satellite EO data may require calibration through local (in situ) sensors on the ground or will only complement in situ data that may be better suited for specific information. In situ sensors range from sophisticated ground stations operated by e.g. municipalities to simple fixed or mobile devices maintained by e.g. citizens. Creating a holistic and accurate view on subjects (e.g. air quality, traffic) requires the integration and validation of the different sensors and systems on the ground and in orbit.

How

- Data generated by a large variety of devices requires standardisation as one crucial step to integration and fusion of data from different sources
- Further, communication protocols and interfaces between devices and systems need to be standardised (and possibly secured) to leverage the myriads of devices able to contribute measurements and data
- Mechanisms need to be put in place to ensure reliability of data coming from both controlled and uncontrolled environments as a step to validate and calibrate data prior to integration
- Accessibility to data for key stakeholders including e.g. municipalities, citizens, or businesses for further analysis or utilisation requires interfaces (i.e. APIs) and/or dedicated portals or dashboards

Who

- **EUSPA**: A designated market officer for urban development should be responsible for guiding approaches to the integration of in situ data and supporting the involvement of "citizen scientists"
- **Standardisation organisations and initiatives**: entities engaged in the standardisation of data (e.g. INSPIRE, GAIA-X) and IoT communication (e.g. IEEE, ETSI) should guide integration efforts
- **Citizen observatories:** initiatives driven by citizens and/or cities to enable citizens monitoring their (urban) environment

Impact

- More accurate and complete data and information
- Inclusion of multiple stakeholders including citizens
- Higher accessibility and utilisation of available information

Impact on	Low	Medium	High
Impact on **end users**			**High**
Impact on **EO service providers**			**High**
Impact on **multipliers**		**Medium**	
Impact on **governance actors**		**Medium**	

3.3.4 Action URBAN 4: Urban Resilience solutions

Action number: URBAN_4	**Timeframe**
Description Land use in urban areas combined with climate change and other factors increasingly reveals vulnerabilities of cities in particular related to extreme (weather) events such as heat or floods. Cities require solutions to monitor such events for immediate response (emergency services), and analyse conditions to predict events and enable longer-term intervention (i.e. planning of water bodies and green spaces, layout changes, relocation of communities).	Short-term 1 – 2 years **Mid-term** 2 – 5 years
How • Capabilities to analyse land use features and environmental conditions in urban areas based on remote sensing and in situ data need to be enhanced • Solutions that enable simulating the impact of mitigating measures need to be developed to enable planning of resilient structures and cities • (Near) real-time capabilities of data and information for emergency response are desired	
Who • **EUSPA**: As an entity governing major space assets utilised for disaster risk management and response (i.e. Galileo, Copernicus, GOVSATCOM), guiding the exploitation of capabilities • **EU Civil Protection Mechanism:** as the platform for exchange among EU27 countries on prevention, preparedness, and response to disasters and with funding to finance civil protection • **Cohesion Policy:** providing funding opportunities for disaster risk management	
Impact • Prevention or mitigation of destructive and life-threatening events • Improvement of health and wellbeing of citizens • Positive economic effect of damage prevention	Impact on **end users**: Low / Medium / **High** Impact on **EO service providers**: Low / Medium / **High** Impact on **multipliers**: Low / Medium / **High** Impact on **governance actors**: Low / **Medium** / High

3.3.5 Action URBAN 5: A tale of Digital Twin Cities

Action number: URBAN_5

Timeframe

Short-term
1 – 2 years

Mid-term
2 – 5 years

Description

Cities are complex structures and proper planning and operations of truly "smart cities" requires data on different levels from city down to neighbourhoods down to individual buildings. Digital Twin simulations are considered key to enable planning smart cities. EO data (in situ, satellite) can provide major contributions to digital models of cities; solutions are required that integrate EO data into such data-rich models.

How

- Solutions need to be in place that are utilising a multitude of EO sensors (optical, radar, thermal etc.) to map built environments and features on and below the surface as well as climate data
- Service providers need to be enabled to integrate or fuse data from various sources and to process these into accessible and comprehensive information
- Computational and analytical capabilities for processing data, modelling, and simulations need to evolve and scale

Who

- **EUSPA**: A designated market officer for urban development should be responsible for the integration of in situ data and the enabling of e.g. "citizen scientists"
- **European Commission:** as coordinator of Destination Earth (DestinE), involving also entrusted entities (ESA, ECMWF, EUMETSAT) in the implementation and with budgets from Horizon Europe and different programmes (incl. Space Programme)
- **DG GROW and DG CNECT:** as entities fostering innovation and digitalisation in construction (e.g. through projects such as CHEK, ACCORD, DigiChecks)

Impact

- Improved planning and decision-making in complex environments
- Cost savings from reduction of bad planning or design
- Visual and data-rich decision support
- Enabling new business models and improved processes for different sectors serving urban spaces

Impact on	Low	Medium	High
Impact on **end users**	Low	Medium	**High**
Impact on **EO service providers**	Low	Medium	**High**
Impact on **multipliers**	Low	Medium	**High**
Impact on **governance actors**	Low	Medium	**High**

3.3.6 Action URBAN 6: Public Procurement innovation

Action number: URBAN_6

Timeframe

Short-term 1 – 2 years | **Mid-term** 2 – 5 years

Description

Public Procurement must be transparent, efficient, and accessible and shall result in useful investments. Solutions are required that enable a number of stakeholders – municipalities, businesses competing for contracts, citizens paying for and potentially benefiting from procured goods and services etc. – to plan procurement of urban development, and monitor progress and compliance.

How

- Provide solutions utilising geospatial data to assess feasibility and cost of development (e.g. buildings, infrastructure, green spaces)
- Implement tools to monitor performance and compliance of construction, integrated in procurement workflows
- Turn public authorities and administrations into anchor clients for EO services

Who

- **EUSPA**: A designated market officer for urban development should be responsible for translating procurement requirements into EO capabilities
- **DG GROW and DG CNECT:** as entities fostering innovation and digitalisation in construction (e.g. through projects such as CHEK, ACCORD, DigiChecks)
- **ICLEI Europe:** as the global network of 2,500+ local and regional governments committed to sustainable urban development, with one of their action fields in procurement & economy

Impact

- Market pull for EO solutions in planning and monitoring construction and post-construction
- Business development for EO service and platform providers providing data, processing, analysis, and technical infrastructure
- Cost savings in permission and compliance checks
- Improved return of investment through better informed decisions and more transparent processes

Impact on	Low	Medium	High
Impact on **end users**			**High**
Impact on **EO service providers**			**High**
Impact on **multipliers**			**High**
Impact on **governance actors**		**Medium**	

3.3.7 Action URBAN 7: Human settlement monitoring

Action number: URBAN_7

Timeframe

Short-term
1 – 2 years

Mid-term
2 – 5 years

Description

With populations growing so are settlements, requiring solutions to monitor and prevent uncoordinated development. Cities need to be able to monitor land use and track changes in a frequent manner with sufficient resolution to distinguish types of land use (e.g. housing, industrial, waste, green spaces, roads) and their performance (e.g. emissions, thermal loss), enabling sustainable urban development.

How

- Provide frequently updated data with sufficient resolution for land use and emissions through more and more capable satellites and/or techniques to enhance existing data
- Further evolve data processing capacities to provide detailed and accurate information on land use and associated emissions and other impacts
- Integrate accessibility and interoperability into data and information design to enable integration in municipalities' information systems

Who

- **EUSPA, DG DEFIS**: A designated market officer for urban development as well as the units responsible for the Copernicus Land Monitoring Service to integrate requirements in their data and service offerings
- **GEO and EuroGEO:** as the partnership organisations fostering use of EO, with Sustainable Urban Development as one of GEO's societal benefit areas, and "Resilient Cities and Human Settlements" as GEO's fourth engagement priority
- **Cities:** to contribute local requirements and ensure applicability

Impact

- Market pull for data from new satellite constellations
- Improved information basis for sustainable cities and increased utilisation of EO data for sustainability goals
- Business development for EO service providers

Impact on **end users**
Low | Medium | **High**

Impact on **EO service providers**
Low | Medium | **High**

Impact on **multipliers**
Low | Medium | **High**

Impact on **governance actors**
Low | **Medium** | High

4 Agriculture

4.1 Where are we now?

Water

Farming uses 70% of the world's fresh water

Emissions

Agriculture, forestry, and other land use causes 23% of greenhouse gas emissions

Biodiversity

Agriculture is the primary driver of biodiversity loss, 24,000 of the 28,000 (86%) species being at risk of extinction

The global food system is under significant strain as it is expected to provide safe and nutritious food to a population that will likely grow from **7.5 billion people today, to nearly 10 billion by 2050**. [23] To achieve this the agro-food sector provides a livelihood to millions of people and represents the main economic resource for a significant proportion of people living in rural areas and facing poverty-related challenges.

Due to increased demand as well as soil degradation or scarcity, the global food system has developed a substantial environmental footprint and has become a major contributor to climate change. OECD highlights that "***agriculture occupies nearly 40% of the earth's surface****, [..] crops irrigation comprises* ***70% of global water use****, and agriculture directly contributes to around* ***11% of global greenhouse gas*** *(GHG)* ***emissions*** *(mostly through cattle)*". Other externalities of agricultural land expansion are deforestation, additional GHG emissions, and a loss of biodiversity.

Focussing on Europe, Agriculture is not only one of the pillars of the European economy – contributing **1.3% to EU's GDP and 4.2% of employment in 2020**[24]; it is also the primary sector where the European Green Deal meets the European Digital Strategy.

The activities put forward in both these pillars will heavily rely on the increased uptake of digital and data-driven solutions thus contributing to the realisation of the Digital Decade for Europe. This transition has been already in motion for many years now with the uptake of a host of technological solutions across all agricultural disciplines; yet, the fulfilment of the EU's vision requires much more to be done in terms of understanding the state of play of digital and data-driven agriculture, pinpointing good practices, key barriers and suitable governance models and, ultimately, disseminating the relevant knowledge and tools to the wider community so as to foster its speedier and more effective adoption.

The following policies and initiatives describe the overarching framework and direction in which the agriculture sector is being guided through international and governmental regulation.

Policy / Initiative	**Description**
EU Green Deal	• The **European Green Deal** sets ambitious targets towards environmental sustainability and economic viability, which in the case of agriculture concern areas such as reduction of the use of pesticides, increase in organic farming output and protection of soils. This effort will be spearheaded by two pillars: the Farm to Fork Strategy and the new CAP, itself including forward looking approaches such as the eco-schemes.
Common Agricultural Policy	• The new **common agricultural policy (CAP)** will be key to securing the future of agriculture and forestry, and achieving the objectives of the European Green Deal.
EIP-AGRI	• The agricultural **European Innovation Partnership (EIP-AGRI)** works to foster competitive and sustainable farming and forestry

[23] https://www.oecd.org/agriculture/key-challenges-agriculture-how-solve/
[24] https://agriculture.ec.europa.eu/system/files/2022-01/agri-statistical-factsheet-eu_en_0.pdf

Policy / Initiative	Description
	that 'achieves more and better from less'. It contributes to ensuring a steady supply of food, feed, and biomaterials, developing its work in harmony with the essential natural resources on which farming depends.
EU Farm to Fork Strategy	• Within the framework of the Green Deal, the European Commission launched in May 2020 the EU Farm to Fork Strategy that aims to ensure a sustainable food value chain. Sustainable agriculture and sustainable fishery within Protected Areas can be a model to provide safe, nutritious, and high-quality products. • In the Strategy, Copernicus features as an invaluable tool for sustainable nutrient management, the protection of soils, the reduction of the use of fertilisers and pesticides, the monitoring of GHG emissions and the preservation of biodiversity.
Biodiversity Strategy	• The EU's biodiversity strategy for 2030 is a comprehensive, ambitious, and long-term plan to protect nature and reverse the degradation of ecosystems. The strategy aims to put Europe's biodiversity on a path to recovery by 2030 and contains specific actions and commitments.

Against this backdrop, the use of digital technologies in farm management and across the agricultural sector is helping to address several farm- and sector-level challenges for farmers, agricultural cooperatives, key decision makers and governments. This ultimately helps to improve farm profitability, address resource-use efficiency and contribute to our sustainability goals. At the micro level, EO allows farmers to effectively monitor the performance of their crops and reduce their usage of inputs such as fertilizers. At the macro level, EO provides vast amounts of rich data which public authorities and economists can use to better inform their analysis and decision making.

The below SWOT analysis covers the strengths, weakness, opportunities, and threats from the **viewpoint of EO-enabled services adoption by the agriculture sector**.

Strengths	**Weaknesses**
- Low-cost, large-scale, all-weather, day-night, continuous monitoring solution - Cost-effective compared to in-situ monitoring solutions - One of the first industries to adopt EO solutions - Proven fit-for-purpose for several operational scenarios	- Lack of technical capacity or conducive mentality on the side of users - Lack of knowledge on the cost-benefit aspects related to the adoption of EO solutions - Lack of procurement procedures with commonly accepted terms of reference
Opportunities	**Threats**
- Increased digitalisation of agriculture operations - EO data can (at least partially) meet increased environmental monitoring requirements - Regulation/policy drivers	- General unawareness of the potential of EO services for agriculture - Lack of skilled personnel in EO technology at farms and agri- companies - Interoperability issues - Data management issues

4.1.1 Market maturity

According to the EUSPA EO and GNSS Market Report 2022, "***Revenues from EO data and service sales in agriculture** are expected to steadily grow in the coming decade, from a combined total across all applications of **€337 m in 2021 to €652 m in 2031**.[25] The applications with the largest market share at present are crop yield forecasting, vegetation monitoring, soil condition monitoring, CAP monitoring, variable rate application, and precision irrigation. When combined, the operational applications of variable rate application of farming inputs and precision irrigation make up the second largest share of the market both now and in the future, accounting for **over €70m in 2021 and almost €168 m in 2031**."* This positive outlook is further reflected on as well as driven by new business models (e.g. EO companies serving Farm Management Software companies in a white label approach thus reaching out to millions of end users) and market developments (e.g. major collaborations between EO data providers and traditional agri-food actors).

4.1.2 R&D trends

The agricultural sector has changed over the last decades, be it due to the changing climate, new crop varieties, more advanced machinery, new scientific insights, or changing policies. These changes significantly impacted how farmers manage their daily operations and how the whole sector, at different levels, **shifts towards a more data-driven approach.**[26]

This evolution is partly due to the increasing amount of EO data and the rapidly evolving remote sensing technology. Although satellite data has been around for a while, thanks to the European Copernicus programme (and especially the Sentinels), viable business models for companies relying on EO data have become a reality. Thus, the ever-increasingly availability of data enables us to develop user-friendly platforms and provide analysis-ready information able to support the decision-making process for various agricultural purposes.

Projects like **ESA WorldCover** and **ESA WorldCereal**, set up for global land cover and cropland monitoring, could never exist without the substantial amounts of available Sentinel satellite data. Weekly agricultural crop monitoring at the field level via **WatchITgrow** would not be possible without the CropSAR service to fuse Sentinel-1 radar data with Sentinel-2 optical data. All these are just very indicative examples of a vast array of cutting-edge services targeting the agriculture sector and relying on EO data. Looking more broadly, with all this influx of data, various R&D trends have emerged related to EO-data-powered solutions in the agriculture industry.

EO solutions in support of Carbon Farming

48% of the EU's surface area is used for agriculture, and the surface layers of the farmlands store many times more carbon than the EU annually emits into the atmosphere. With the right farming practices, these carbon stocks can be contained, and land can absorb more carbon from the atmosphere. According to the EUSPA EO and GNSS Market Report 2022, *"EO technologies are being used to monitor and maintain agricultural practices that increase carbon stocks, such as the maintenance of permanent grasslands. 'Carbon Farming' is a relatively new term that refers to the monitoring and management of increased CO2 absorption in farm soil".*

Using EO technologies, large geographic areas can be constantly monitored, meaning Carbon Farming incentive schemes can operate much more efficiently, reducing inspection costs and helping to increase compliance. In 2021 the European Commission published a comprehensive technical guidance handbook for implementing result-based carbon farming mechanisms. These included approaches to carbon credit trading schemes for farmers. Carbon

[25] EUSPA EO and GNSS Market Report 2022 https://www.euspa.europa.eu/sites/default/files/uploads/euspa_market_report_2022.pdf
[26] https://blog.vito.be/remotesensing/eo-for-agriculture

farming is a promising candidate for helping to meet future greenhouse gas emission targets and will undoubtedly become more prevalent in the near term.

The rise of EO solutions in organic farming

For farmers to derive benefits from organic farming methods, consumers need to trust that the rules on organic production are followed, requiring special certification. Therefore, certification control is a condition for organic farmers to fulfil mainly based on farmers' accounting records. According to the EUSPA EO and GNSS Market Report 2022, "*The reliability of accounting control becomes more questionable when a farmer practices both organic and conventional agriculture on their land. EO technologies have the potential to enable efficient, cheap, rapid, and accurate organic certification control*".

ESA has been working with Ecocert, an organic certification organisation, to use satellite images to spot differences between traditional and organic farming to facilitate the certification process. Multi- and hyperspectral satellite imagery with 80% to 100% accuracy rates is used to derive indicators based on biophysical justification and crop management practices to differentiate between these methods.[27]

Sustainable management of soils

The interest in restoring soil health has recently increased due to intensive agriculture, inappropriate land management practices (e.g., overuse of fertilizers), and the amplifying presence of climate change. New policy regulations, such as CAP and the SDGs, have brought together the relevant stakeholders (e.g., farmers, policymakers, etc.) ahead of a great challenge to tackle soil health issues.

EO can support soil monitoring in the EU Soil Thematic Strategy framework for 2030, with developed capacities towards soil degradation (covering soil sealing, erosion, and desertification). According to the EUSPA EO and GNSS Market Report 2022, "*Satellite-based EO in conjunction with ground measurements (e.g., from the Land Use/Cover Area frame Survey (LUCAS) soil monitoring system) are an essential tool for the monitoring, reporting and verification of soil condition and carbon capture potential – the latter is an area receiving increased attention from market players*."

4.2 Where do we want to be?

The desired future for EO in the agriculture sector can be summarised as follows: EO shall become an integral tool helping the actors of the agriculture value chain produce the needed amounts of food while reducing the associated environmental footprint. To do so a few key dimensions have been identified through the FIRE community.

4.2.1 Widespread adoption of EO in support of CAP

Both the new CAP 2023-2027 and the Farm to Fork Strategy mentioned previously make explicit reference to the use of EO in support of respective activities. This echoes actual developments in the market with multiple Paying Agencies adopting EO-based solutions, albeit in a relatively slow pace. This, as well as the fact the new opportunities for EO use arise (e.g. eco-schemes), means that there is still quite some way to go until EO has truly become widely adopted.

[27] https://www.esa.int/Applications/Observing_the_Earth/Certifying_organic_crops_from_space

4.2.2 Uptake of EO in new initiatives related to agriculture

As mentioned above, new paradigms have been gaining in recent years significant momentum such as Carbon Farming. Moreover, new opportunities are also on the horizon in relation, for instance, regenerative agriculture and management of plant growth regulators. This creates significant scope for the development of smart solutions relying on EO and exploiting AI/ML techniques. A large number of R&D projects has been looking into such concepts seeking to develop, demonstrate and eventually operationalise EO-based solutions with the direct involvement of relevant users. Such efforts need to be further supported in the future.

4.2.3 Strengthening and transparency of agricultural supply chains

The use of EO is not only connected to field-level advice for the individual farmer. It is also underpinning the work of governments or international organisations monitoring food production information within the context of commodities markets and early warning of production shortfalls (which is precisely the scope of GEOGLAM[28] for instance). More than that, transparency and traceability in agricultural value chains has become an imperative in recent years not only due to increasing consumer awareness but also thanks to regulatory developments that push the involved supply chain actors to minimise their environmental footprint[29]. These efforts require further development of EO-based tools as well as market development support to ensure that (i) relevant users are aware of the strengths of EO for their purposes, (ii) EO service providers can effectively scale up their offering.

4.2.4 Upscaling of EO uptake inside and beyond the EU

Agriculture has been one of the first sectors seeing successful commercial ventures by EO service providers. This was further enabled after the advent of the Sentinel era with several companies rolling out viable business models thanks to (i) the free, full and open policy of Copernicus, (ii) the fact that the requirements of many applications could be effectively met with the technical value proposition of the Sentinels. Still though, several of the start-ups or young SMEs serving this sector have not managed to scale up and expand their offering across borders yet. Given the intrinsic possibility to serve clients across the globe there is abundant scope for internationalisation and upscaling support. This becomes even more prevalent when considering the dependencies of global agricultural supply chains and the need for the EU to produce food sustainably.

4.2.5 Strengthening the capacity of the demand side

An important issue highlighted during the FIRE Focus Group sessions and the FIRE Fora, but also repeatedly brought up in virtually any relevant user engagement event (be it in the course of EU-funded projects, in activities by relevant networks or in dedicated sectorial workshops) is that of strengthening the capacity of the demand side. Farmers and other value chain actors (e.g. Paying Agencies) may lack the necessary capacities to make the most of the information provided by EO services. This can range from lack of fundamental awareness of what is possible with EO to possessing the technical tools to integrate EO services in their operational workflows seamlessly and all the way to being part of a well-organised governance scheme (involving also governmental actors, investors,

[28] https://cropmonitor.org/
[29] See for instance https://earsc.org/sebs/deforestation-monitoring-for-sustainable-palm-oil-production/

insurers, etc.). With increased focus on the digitalisation of the sector this need will become more prevalent and therefore requires comprehensive response to address it.

4.3 How to get there?

To reach the desired developments discussed previously a number of actions can be pursued.

4.3.1 Action AGRI 1: Promote wider adoption of EO solutions in support of CAP

Action number: AGRI_1	**Timeframe**
Description This action should focus on the upscaling of EO solutions in support of established CAP-related applications on one hand and the piloting of EO solutions for new aspects of CAP on the other. For the former, the primary aim would be to expand the use of EO for CAP monitoring related to subsidy claims building on a series of results from funded projects, in line with recommendations by the European Court of Auditors[30] (ECA). For the latter, the focus should be on eco-schemes as the main innovation in the green architecture of the [new CAP 2023-2027](). The eco-schemes, being now mandatory instruments for which Member States should allocated at least 25% of the budge for direct payments in line with their own CAP Strategic Plans, concern aspects such as mixed cropping - multi cropping, establishment and maintenance of permanent grassland, precision crop farming to reduce inputs (fertilisers, water, plant protection products) and improving irrigation efficiency. As can be readily seen many of these aspects can be supported by EO-based solutions.	Short-term 1 – 2 years **Mid-term** 2 – 5 years

How

This action should be implemented in a three-pronged approach.

- **State-of-play**: Following the findings of ECA in 2020 and in light of new advances in the meantime (e.g. work in Slovenia[31]) it is essential that a thorough account of current practices, operational issues (incl. procurement aspects), technological developments and evolving EO value proposition is created. This can be supported by actors such as EUSPA in collaboration with DG AGRI and relevant communities (e.g. SMART-AKIS, EIP-AGRI, etc.).
- **Awareness Raising:** Given that eco-schemes will be implemented through the CAP Strategic Plans it is critical that relevant actors are properly informed about the value proposition and practical implementation guidelines of EO-based solutions in this context. Here too, collaboration between market development actors (e.g. EUSPA) and competent authorities (DG AGRI, JRC) could be beneficial. Particular focus should be placed on actively training Paying Agencies on procurement aspects so that they are practically capable of adopting such solutions.
- Launch of **R&D&I activities**: Ideally supported by a mix of instruments (e.g. Horizon Europe, Copernicus Demonstrators, ESA Expand Demand), this would allow the piloting and operationalisation of EO-based solutions through collaboration of the actors across the whole value chain.

For this action to have a greater impact, concrete KPIs need to be set up in coordination with the overall Copernicus User Uptake Strategy.

[30] https://op.europa.eu/webpub/eca/special-reports/new-tech-in-agri-monitoring-4-2020/en/
[31] https://learn.planet.com/cap-area-monitoring-system-webinar-registration.html

Who

- Competent EC actors – DG AGRI, DEFIS, RTD | EUSPA | ESA
- Member State actors – Ministries responsible for CAP Strategic Plans and Paying Agencies
- Relevant networks (e.g. SMART-AKIS, EIP-AGRI, EIT FOOD)
- EO Service Providers (ideally coordinated through EARSC)

Impact

- Increased adoption of EO solutions for established CAP-related activities
- Uptake of EO solutions for eco-schemes under the new CAP

Impact on **end users**		
Low	Medium	**High**

Impact on **EO service providers**		
Low	Medium	**High**

Impact on **multipliers**		
Low	**Medium**	High

Impact on **governance actors**		
Low	**Medium**	High

4.3.2 Action AGRI 2: Streamline the use of EO for Carbon Farming

Action number: AGRI_2

Timeframe

Short-term
1 – 2 years

Mid-term
2 – 5 years

Description

Following the publication of the final report of a two-year study on how to set up and implement **carbon farming** in the EU, the EC has issued a technical handbook and associated guidelines[32]. These make explicit reference to Copernicus but also to some of its limitations (which can be to a large extent overcome with higher-resolution data). Since then, the EC has been providing recommendations on how to implement Carbon Farming schemes under the CAP but also organising dedicated workshops[33] - concluding *inter alia* that *remote sensing technologies are a desirable tool to improve farm and forest level monitoring*. In light of this, this action should support the streamlining of EO-based solutions for Carbon Farming.

How

This action should be implemented with a similar logic as AGRI 1 described before. This means conducting **focussed state-of-play analysis** that lays out (i) the key policy initiatives driving Carbon Farming activities (including CAP and F2F), (ii) industry-led initiatives that seek to put carbon farming into practice through a wide range of activities, (iii) the projects currently ongoing or planned. The results of this analysis should feed directly into the specifications for upcoming **R&D&I** supported, as before, through a multitude of instruments (Horizon Europe, Copernicus Demonstrators). Of key importance here is the involvement of stakeholders who have been championing carbon farming and the use of EO in this context. This includes *inter alia*

- The European Carbon+ Farming Coalition as a brand new, farmer-centric initiative with the aim to accelerate progress toward European Green Deal carbon neutrality goals
- The Carbon Cycle Institute – Who promote carbon farming heavily and aim to stop and reverse global climate change by advancing science-verified solutions that reduce atmospheric carbon.
- EIT Climate KIC, who have been championing the efficacy of Carbon farming - link

Who

- Competent EC actors – DG AGRI, DEFIS, RTD | EUSPA | ESA
- Member State actors – Ministries responsible for CAP Strategic Plans and Paying Agencies
- Relevant networks (e.g. see above)
- EO Service Providers (ideally coordinated through EARSC)

[32] https://op.europa.eu/en/publication-detail/-/publication/10acfd66-a740-11eb-9585-01aa75ed71a1/language-en
[33] https://climate.ec.europa.eu/system/files/2021-07/20210525_workshop_iv_report_en.pdf

Impact	
• Increased adoption of EO solutions for established Carbon Farming initiatives • Improved scientific and technical solutions feeding into Carbon Farming aspects (e.g. EO-based approaches for monitoring, reporting and verification)	Impact on **end users** Low **Medium** High Impact on **EO service providers** Low Medium **High** Impact on **multipliers** Low **Medium** High Impact on **governance actors** Low **Medium** High

4.3.3 Action AGRI 3: Empower users to make the most of EO-based solutions

<table>
<tr><td>Action number: AGRI_3</td><td rowspan="2">Timeframe

Short-term
1 – 2 years
Mid-term
2 – 5 years</td></tr>
<tr><td>Description
Among the most frequently quoted challenges for the adoption of EO-based solutions in agriculture are capacity-related issues: general awareness, technological savviness, reluctance for paradigm changes, access to the necessary underlying infrastructure, interoperability problems (i.e. hardware-software). Thus, whether looking into expanding the adoption of EO in established practices or introducing it into new ones, strengthening the capacity of users and empowering them to make the most of EO is essential.</td></tr>
<tr><td colspan="2">How
This action should entail a series of capacity building activities forming part of a comprehensive programme. Thus, firstly the programme itself should be drafted in collaboration between DG AGRI and DG DEFIS with the involvement of key stakeholders on the demand side (e.g. representatives of farmers such as COPA-COGECA, Paying Agencies, Agricultural Consultants). The programme should distinguish between the different user segments (and by application) and the different capacity-related issues mentioned in the description above. For each of these issues best practices should be documented and replicated through the mobilisation of relevant networks. This includes larger communities (e.g. ENRD, SMART-AKIS, EIP-AGRI) but also specialised ones (e.g. building on the FIRE Focus Group or EUSPA's UCP) and even informal communities established through projects (e.g. IOF 2020, Sen4CAP). The programme would act as connecting tissue between ongoing, planned or brand new actions funded through various means but assessed against clear KPIs and expected impacts in a comprehensive manner. This would ensure optimisation of public funds and investments. When it comes to brand new actions these should focus on aspects that can unlock the upscaling of EO solutions adoption in line with the upcoming Copernicus User Uptake Strategy but also the spirit of EuroGEO. Ultimately, the aim of this action would be to ensure that the impact of individual capacity building activities organised under different projects and initiatives is enlarged and spread out to much wider user communities.</td></tr>
<tr><td colspan="2">Who Competent EC actors – DG AGRI, DEFIS, RTD | EUSPA | ESA Member State actors – Ministries responsible for CAP Strategic Plans and Paying Agencies Relevant networks and associations EO Service Providers (ideally coordinated through EARSC)</td></tr>
<tr><td>Impact Increased adoption of EO solutions across applications in the agriculture sector Optimised use of public funds and investments</td><td>Impact on end users: Low | Medium | High
Impact on EO service providers: Low | Medium | High
Impact on multipliers: Low | Medium | High
Impact on governance actors: Low | Medium | High</td></tr>
</table>

4.3.4 Action AGRI 4: Strengthen solutions relying on EO for global food security monitoring

Action number: AGRI_4	**Timeframe**
Description For years now EO has been used to monitor global food security with focus on early warning for potential shortfalls and associated disruptions in the supply chain. This has unfortunately become even more urgent following recent geopolitical events. Strengthening the capabilities of EO-based monitoring systems in this regard is therefore essential.	Short-term 1 – 2 years **Mid-term** 2 – 5 years
How This action should be implemented through RIA or IA actions supported by Horizon Europe and/or other "faster" instruments (in terms of rolling out public funds and getting back desired results). It should focus on strengthening monitoring systems connected to GEOGLAM but also regional monitoring capabilities (such as those activated for Ukraine following the agricultural supply chain crisis triggered by the war). This would require optimal exploitation of both satellite and in-situ observations, with the former combining Copernicus data with commercial ones where needed. Data and information sharing should have a central role in these efforts in accordance with associated principles and in close connection with ongoing initiatives such as the common European agricultural data space. Finally, best practices around data governance and transparency such as those exhibited in national or regional solutions (e.g. see WatchITGrow mentioned before) should be replicated.	
Who • Competent EC actors – DG AGRI, DEFIS, RTD | EUSPA | ESA • GEOGLAM • EO Service Providers (ideally coordinated through EARSC) • Agriculture Data Governance Networks and initiatives	
Impact • Increased adoption of EO solutions for global food security monitoring • Improved scientific, technical and data governance solutions enabling actors across the value chain to gain access to insights generated by EO solutions	Impact on **end users**: Low / **Medium** / High Impact on **EO service providers**: Low / **Medium** / High Impact on **multipliers**: Low / **Medium** / High Impact on **governance actors**: Low / **Medium** / High

4.3.5 Action AGRI 5: Support internationalisation and upscaling of EO companies in the Agriculture sector

<table>
<tr><td>Action number: AGRI_5</td><td rowspan="2">Timeframe

Short-term
1 – 2 years
Mid-term
2 – 5 years</td></tr>
<tr><td>Description
Several EO companies have developed in the past years (especially since the advent of the Sentinels era) strong proposition for the agriculture sector. At this point a comprehensive effort to help them scale and internationalise is needed, allowing to grow and export EU excellence.</td></tr>
<tr><td colspan="2">How
The key point for the success of this action is to move away from ad hoc and fragmented efforts and towards comprehensive support. This can be realised through (i) the identification of companies having a strong case of upscaling/internationalisation perspectives with solid business plans, good market traction and proven technological excellence – these may have benefitted from EU funds in the past but should demonstrate that they are committed to enter the real market; (ii) the mobilisation of CASSINI funds and supporting activities, focussed specifically on the internationalisation and upscaling of EO service providers active in agriculture; additional support can be provided through the upcoming ESA Scale Up programme as well as through EIC/EIF efforts and (iii) the exploitation of existing internationalisation pipelines (e.g. through EARSC’s ConnectEO or the Global Action for the EU Space Programme).</td></tr>
<tr><td colspan="2">Who
EUSPA in its mission of market development support
Existing internationalisation programmes (e.g. Global Action for the EU Space Programme)
EO Service Providers (ideally coordinated through EARSC)</td></tr>
<tr><td>Impact
Increased revenues for EO service providers with a strong value proposition in the agriculture sector
Industrial growth and technological leadership for the EU</td><td>Impact on end users: Low (Medium, High)
Impact on EO service providers: High (Low, Medium)
Impact on multipliers: Medium (Low, High)
Impact on governance actors: Low (Medium, High)</td></tr>
</table>

5 Wind energy

5.1 Where are we now?

Boosting the share of renewables is at the heart of the EU's strategic objectives for energy and climate, being an important contributor to the reduction of greenhouse gas emissions and a key factor in the drive for energy independence. Targets for the share of energy derived from renewables have been tightened in a series of key policies, such as the EU Green Deal[34] , the Fit for 55[35] package, and then most recently in the RePowerEU plan[36].

Note: although wind energy has been selected for study in FIRE, in many cases the needs of the industry are very similar to related industries. For example, other parts of the offshore renewable sector (such as tidal energy) have very similar needs to MetOcean parameters, while topics such as site impact assessment are common to a wide range of installations. Wind energy should therefore be seen as a specific case study for needs which apply more broadly.

The RePowerEU plan raises the target for renewables to 45% (corresponding to energy generation capacities of 1,236 GW) by 2030 and lays out concrete measures to make Europe independent from Russian fossil fuels well before 2030, accelerating the green transition and increasing the resilience of the EU-wide energy system. In practice, this plan mobilises funds and puts in place legislation that can catalyse the deployment of renewables especially in dedicated "go-to areas" with low environmental risk.

Wind Energy (both onshore and offshore) is a key pillar of the strategy for reaching these targets. The target is for wind energy production to grow from 190 GW today to at least 480 GW in 2030[37], representing an installation of more than 30GW additional capacity per year. This is expected to primarily come from offshore wind farms, though with onshore wind also in the mix.

To meet this capacity, the deployment of Wind Farms needs to be massively accelerated. A number of significant barriers to this deployment exist, which have been highlighted in the findings of the Focus Group discussions with representatives of the sector. The most significant barriers include:

- **Permitting**: this is considered the single biggest bottleneck for the accelerating of wind energy uptake. At present it may take up to 10-12 years for offshore wind parks to receive permission. Closely tied to the issue of permits is the ability to derive the layout of wind farms so as not to cause a significant change in the weather patterns at sea or to impact migratory patterns of biodiversity (birds, bats, sea mammals) who share the space.
- **Co-existence with other economic activities**: Large territories may be excluded due to geopolitical or economic restrictions, e.g. a large part of France has been blocked as it was characterised by the MoD as a low-fly zone.
- **Manufacturing:** as is the case with solar panels, so too with components of wind turbines, the robustness (in terms of producing the necessary volumes) and autonomy (in terms of retaining access to needed raw materials or parts) of the supply chain is essential.

Beyond these barriers, the industry (as represented in the FIRE activities) has underlined how the wind energy sector faces additional challenges as it evolves and matures. For instance, wind turbine towers are getting much higher making the need for accurate models on wind conditions monitoring even greater than before. Similarly, the

[34] https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal/energy-and-green-deal_en
[35] https://www.consilium.europa.eu/en/press/press-releases/2022/06/27/fit-for-55-council-agrees-on-higher-targets-for-renewables-and-energy-efficiency/
[36] https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal/repowereu-affordable- secure-and-sustainable-energy-europe_en#repowereu-actions
[37] https://windeurope.org/newsroom/press-releases/north-sea-offshore-wind-to-help-repower-the-eu/

ability to perform accurate impact assessment of farms becomes crucial. Moreover, novel approaches seek to integrate wind energy with other modes (primarily ocean wave but also solar) and the production and storage of green hydrogen.

In all this, EO has a strong value proposition. EO data is readily available, including in high spatial resolution, but the temporal resolution (of Copernicus for instance) is often not sufficient. This gives rise to the need to combine remotely sensed EO data with in-situ observations. The EO solutions that stand out, especially for offshore wind energy, include SAR (higher spatial resolution & proven technology to map wind around wind farms) and ASCAT (coarser resolution but readily available several time per day, more used for larger area mapping). Such data have been incorporated in the offerings both from EO service providers but also from advanced users themselves. Yet, certain technical challenges persist. For instance, EO wind retrievals are at the sea surface, which means that synergies need to be found with other data to extrapolate to heights of wind turbines (100m).

The following policies and initiatives describe the overarching framework and direction in which Wind Energy policy is being guided through international and governmental regulation.

Policy / Initiative	**Description**
EU Green Deal	The European Green Deal focuses on 3 key principles for the clean energy transition, which will help reduce greenhouse gas emissions and enhance the quality of life of our citizens: • ensuring a **secure** and **affordable EU energy supply** • developing a **fully integrated, interconnected** and **digitalised EU energy market** • prioritising **energy efficiency**, improving the **energy performance of our buildings** and developing a power sector based largely on **renewable sources**
European Climate Law	Sets a legally binding target of **net zero greenhouse gas emissions by 2050 and** includes **measures to keep track of progress and adjust our actions accordingly. Sets** an ambitious 2030 climate target of at least 55% reduction of net emissions of greenhouse gases as compared to 1990, with clarity on the contribution of emission reductions and removals. Includes a commitment to engage with sectors to prepare sector-specific roadmaps charting the path to climate neutrality in different areas of the economy.
RePower EU	Raises the target for renewables to 45% (corresponding to energy generation capacities of 1,236 GW by 2030) and lays out concrete measures to make Europe independent from Russian fossil fuels well before 2030, accelerating the green transition and increasing the resilience of the EU-wide energy system
EU Strategy on Offshore renewable energy	Proposes concrete ways forward to support the long-term sustainable development of this sector. The strategy sets targets for an installed capacity of at least 60 GW of offshore wind. The strategy addresses broader issues, including the technological transfer of research projects from the laboratory into practice.

Against this overall backdrop, it becomes apparent that EO is uniquely positioned to support many of the wind energy related activities. The below SWOT analysis covers the strengths, weakness, opportunities, and threats from the **viewpoint of EO data enabled services adoption by the wind energy sector**.

Strengths	Weaknesses
- Low-cost, high-resolution monitoring of offshore wind farms. - Cost-effective compared to in-situ monitoring solutions for offshore wind. - Broad monitoring allows for incorporation into wider supply and demand models	- Many user needs are better met through improved weather forecasts rather than standalone applications. - Significantly fewer EO-based use cases for onshore wind farms. - Needs fusion of EO with in-situ & other data sources for potential to be fully realised.
Opportunities	**Threats**
- Significant industry expansion ongoing with keen interest in solutions which can optimise operations. - Expansion of SAR constellations gives more frequent acquisitions of relevant data. - Needs of the wind industry closely align with those of other industries, giving a strong potential for synergetic applications.	- Lack of EO expertise within the wind energy industry ecosystem. - Need to demonstrate cost effectiveness of EO based solutions to key decision makers.

Beyond the points discussed above a few general challenges seen across the Wind Energy industry include:

- Some data is still not yet available at the resolution and revisit time at which they become useful for the sector.
- General understanding that EO should not take over the current methods, but supplement (or “marry”) them.
- Low estimated ROI, leading to a lack of funding
- Low level of integration with in-situ measuring systems
- Conservatism and disturbance of the traditional workflows

5.1.1 R&D trends

In the next years, the following applications of earth observation are expected to become generally available and widely used, driven by the overall market trends, the specific needs of actors in the sector, and the advances in technological capabilities:

Optimizing prediction models for weather, output and operations. Forecasting how much energy will be produced at short to medium timescales will become more necessary as the penetration of wind energy into individual grids increases. Therefore, reducing uncertainties of wind speed and direction is crucial. Although there has been progress in offshore wind (see below), the determination of onshore wind is still in its infancy.

Innovations in offshore wind. Offshore wind farms are complex developments in all their stages, with challenges at all stages: design, construction, maintenance, operations and decommissioning. Moreover, as more regions are developed, wind farms are being placed in different regions (e.g. further from the shore), bringing a series of new challenges, which earth observation data are well placed to help. Some of these areas are specific to wind energy, others (such as environmental impact assessments) apply in many domains.

Predicting future energy demand and supply. For stable electrical grids the energy generated must be equal to the energy consumed, despite natural fluctuations. Using weather dependency renewable energy sources adds to the number of variables involved. Smart grids help monitoring the equipment’s health, but there are still many challenges to be solved around forecasting energy data or managing grid flexibility. Solving the issues of predicting energy usage and supply is a key challenge, both over short timescales and when looking at longer timeframes for the purpose of resource planning. Earth observation is one of many factors that can play a role here.

5.1.2 Market maturity

Earth observation is already used for many applications in the field of Wind Energy, especially for offshore wind farms. However, to extract the full benefit, EO data must be combined with a large number of other sources (either to create weather forecasts or other more bespoke services) so it is difficult to precisely attribute the benefits from EO alone.

According to the EUSPA Market Report 2022, the total amount of EO data and services for the energy and raw materials sector in 2020 amounts to €305 Million worldwide. Out of this around 24% (73 M€) relates to renewable energy site selection, planning and monitoring, while a further 10% (31 M€) related to renewable energy assessment potential and forecast. The report does not define what fraction of these figure are specific to wind energy, but it is clear that there is a sizeable amount.

5.2 Where do we want to be?

5.2.1 Overview

This section lists some of the key areas identified for the inclusion of EO into the workflows of wind energy companies. Although some of these are specific to the wind industry, many of these are common across multiple industries. For example, ecosystem impact assessments will be carried out for many types of infrastructure, not just wind farms, and similarly the utility of integrated supply and demand models will go beyond the wind industry. To a large extent, the benefits of EO to the wind energy industry are subsets of the broader benefits of EO.

Moreover, none of the identified applications are purely EO. All can be (and are) performed to some degree using ground-based instruments and techniques. It is therefore expected that EO will be used to supplement and improve existing applications, rather than replacing them. The focus should be on how EO can best be used within the current framework, improving the results for the end user.

5.2.2 MetOcean Parameter Measurement

The location of offshore wind sites is largely determined by the availability of sufficient wind energy, based on long term trends at the selected site, while real time measurements of wind are critical to ongoing operations. Other MetOcean parameters, such as sea level, currents and wave heights, provide important information in determining the conditions under which a wind farm must operate.

Wind measurement for offshore wind farms is done through a mixture of in situ sensors and LIDAR instruments, together with modelling to show the propagation of wind across the site. Satellite based measurements using scatterometry and SAR are an alternative means of measuring offshore wind patterns, both for analysis of long terms trends (important in site selection) and for input to operations. These techniques estimate the sea surface wind speed and direction based on the patterns of reflection, and can give a more localised forecast than those available from a typical weather forecast. Altimetry can be used to determine the sea surface level and significant wave height, also inferring the underlying current, giving indication of the conditions that offshore installations are exposed to.

There has been significant research into the use of such techniques for the offshore wind industry, and there are several existing means by which the industry can access MetOcean parameters (either long term histories or real time data), but there is still further work that needs to be done here.

5.2.3 Localised Weather Prediction

Wind energy, but its very nature, relies on atmospheric conditions at a specific site. The ability to predict the wind speed and direction at the site is critical to ongoing operations. Other parameters, such as precipitation or (for offshore) wave heights may also impact the operation of the site.

To a large extent this is a specialised instance of weather forecasting, for which Earth Observation is a key input (mainly through specialised weather satellites such as those operated by EUMETSAT). There is already a flourishing ecosystem of organisations dedicated to providing improved weather forecasts, and this should be treated separately to EO services.

However, there is still a need for more localised services that can be provided by EO. Ideally wind farm operators need very precise forecasts at the turbine scale. Such forecasts are used for optimising the operation of each turbine, as well as for supporting decisions on the best times for maintenance periods.

For offshore installations EO can support this through the measurement of offshore wind (see above), using SAR and scatterometry to measure sea surface winds. Since there is some delay before the measurements are available, and since the active turbine may be up to 100m above the sea surface, some degree of modelling is needed to translate these measurements into wind speed as experienced by the turbine.

In addition to periodic weather forecasts, improved warning of extreme events is needed by the industry, but this is largely within the domain of standard weather forecasting. Site specific forecasts, including EO measurements, may play a role in determining how much impact a given event is expected to have on a specific installation.

5.2.4 Integrated Models of Supply and Demand

The weather not only determines the availability of wind energy, it also strongly influences the demand for electricity from all sources. Recognising this, an extension of the above concept is to look at integrated models of both supply of and demand for electricity. This can be used for planning the operations of a wind farm, as well as of the supply more broadly.

For such models EO data will be one of many sources of data, including weather forecasts, in situ data, socio economic data and historic records of electricity demands. The aim here should therefore not be to develop standalone solutions, but to ensure that the developers of such models are fully aware of the potential of EO data and have access to sufficient expertise. Achieving this will require several actions, both to raise awareness and to build skills.

As well as looking at short-term planning, models can also be used for analysing long term trends in both energy potential and energy demand. This could be a use case for the ongoing DestinE initiative[38].

5.2.5 Ecosystem Impact Assessment

[38] https://digital-strategy.ec.europa.eu/en/policies/destination-earth

When planning wind farms, as well as looking at capacity for energy generation it is also important to look at the impact developments will have on the local environment. EO can be used to support such efforts, allowing an initial assessment of the site remotely and enabling a look at long term trends in the region.

This service applies both to offshore and onshore wind farms, although the techniques applied are likely to be very different in the two cases. For both on and offshore the service is not unique to wind farms but could be used by other developments. In fact, this service will be in high-demand in the near future given the requirement embedded in the RePowerEU plan to identify and monitor “go-to-areas” for the deployment of wind farms (and other renewables).

5.3 How to get there?

5.3.1 Action WIND 1: Awareness-Raising in the wind energy industry

<table>
<tr><td>Action number: WIND_01</td><td rowspan="2">Timeframe

Short-term 1 – 2 years   Mid-term 2 – 5 years</td></tr>
<tr><td>Description

Further promote awareness of Earth Observation within the wind industry, with the aim of increasing the uptake of current services by key players. The dialog established will also serve to build relationships between the two communities, while increasing interest in further developments ahead of subsequent actions.</td></tr>
<tr><td colspan="2">How

Establish a working group to coordinate outreach to the Wind Energy industry. This group should:
Prepare material showcasing existing case studies of how Earth Observation has benefited the wind energy industry.
Use relationships with industry bodies to communicate this material to a wider audience, e.g. through news articles in industry publications.
Ensure significant EO representation at key wind industry events, through submitted presentations, manned stands, or side event organisation. The continuation of the FIRE EO Evangelist programme could also be foreseen.
Use such initiatives to build a dedicated network of contacts who are interested in exploring further the uses of EO within the wind industry. Social media groups (e.g. LinkedIn) can be used as a focal point for the groups.
Arrange webinars or other outreach targeted specifically at this network.</td></tr>
<tr><td colspan="2">Who
EUSPA are already undertaking actions to engage the renewable energy industry, among others, and therefore would be an appropriate choice to lead the outreach.
EARSC represent the European EO Industry and can coordinate the outreach by EO service providers.
WindEurope represent the wind energy industry within Europe and are already involved in several relevant projects (including FIRE). As such they are well positioned to advise on how the outreach can be effectively targeted to reach the key stakeholders.</td></tr>
<tr><td>Impact

This action should be seen as a prerequisite for subsequent actions, building up the community that will participate in further research. Key impact is in the spread of awareness about EO within the wind energy community.</td><td>Impact on end users: Low / Medium / High

Impact on EO service providers: Low / Medium / High

Impact on multipliers: Low / Medium / High

Impact on governance actors: Low / Medium / High</td></tr>
</table>

5.3.2 Action WIND 2: Demonstrate value of EO in various operational wind energy scenarios

Action number: WIND_02

Timeframe

Short-term	Mid-term
1 – 2 years	2 – 5 years

Description

Support key case studies of EO use within the wind energy industry, covering themes which have been established as areas of high interest. As well as being valuable research in its own right, these will also serve to further promote EO within the industry, while building bridges between the EO and Wind industry by giving them the opportunity to work together on a key project.

How

Provide funding for a series of case studies for improved usage of Earth Observation (and derived Copernicus services) by the wind energy industry. These should be designed such that are being undertaken as a cooperation between EO service providers and representatives of the wind energy industry, by requiring both detailed EO knowledge but also assessment of real-world improvements in operational settings.

The areas identified for the subject of these case studies are:

- Localised wind measurement and prediction
- Offshore site selection
- Improved maintenance planning

Funding for these case studies could be provided either through a Horizon Europe call (IA), or through a call similar to the “Copernicus Demos” ITT issued by EUSPA.

Who

- **DG ENER** is responsible for the EU’s energy policies and could lead the issuing of appropriate Horizon calls.
- **EUSPA** are already engaging with the renewable energy industry, among others, and could be an alternative funding agency for the calls.
- **ETIPWind** support the definition of R&I priorities in Europe, and should be consulted on the final form of the calls issued.

Impact

- Benefits to end users: new solutions based on EO meeting real user needs.
- Benefits to EO service providers: new opportunities to develop and promote solutions to the wind industry.
- Multipliers: building links between the two communities that will last beyond the immediate project lifetimes.

Impact on	Low	Medium	High
Impact on **end users**	Low	**Medium**	High
Impact on **EO service providers**	Low	**Medium**	High
Impact on **multipliers**	Low	**Medium**	High
Impact on **governance actors**	Low	**Medium**	High

5.3.3 Action WIND 3: Develop integrated supply and demand models exploiting EO and Copernicus

Action number: WIND_03

Timeframe

Short-term
1 – 2 years

Mid-term
2 – 5 years

Description

Development of integrated supply & demand models for the renewable energy industry, ensuring that they fully exploit the capacities of Earth Observation and Copernicus.

How

An integrated model of demand and supply has been identified as a key industry priority. Development of such a model is likely to be a large-scale undertaking, requiring inputs from multiple sources, and so dedicated investment through a Horizon call will be required. This need not consider only wind energy, but also other categories of renewables such as ocean energy.

EO data will be a critical input and should be fully incorporated into such models, either directly or through the Copernicus services. However, it is only one of many sources, and so EO will not be the only focus of this development, which should rather be conducted from an end user perspective.

Who

- **DG ENER** is responsible for the EU's energy policies and could lead the issuing of appropriate Horizon calls. This could also be done through **DG RTD**.
- **ECMWF** are responsible for the Copernicus Atmosphere and Climate Change Services, as well as for numerical weather forecasting within Europe, and should be involved in the definition of models that will make heavy use of their input data.
- **ETIPWind** support the definition of R&I priorities in Europe, and should be consulted on the final form of the calls issued.

Impact

- The key output is the availability of an integrated demand and supply model available to regulators and industry,
- Technical impacts include improved accuracy of the model outputs against currently used methods, e.g. more accurate and timely prediction of critical periods (high demand/low supply).

Impact on **end users**		
Low	**Medium**	High

Impact on **EO service providers**		
Low	Medium	High

Impact on **multipliers**		
Low	Medium	**High**

Impact on **governance actors**		
Low	Medium	**High**

5.3.4 Action WIND 4: Develop long-term forecasting capabilities

Action number: WIND_04	**Timeframe**
Description The development of long-term forecasting capabilities enabling realistic planning of the required wind energy capabilities is essential for the realisation of the ambitious goals under RePowerEU.	Short-term 1 – 2 years **Mid-term** 2 – 5 years

How

Building on the development of an integrated model of demand and supply, a further step is needed to look at the long-term requirements, predicting energy needs over a timescale of decades. This should be done by linking the industry's own models to long term projections of both demand for electricity and of wind supply in a changing climate.

This task is a natural fit to the Destination Earth (DestinE) initiative, and should be linked to this activity, either through being specifically performed as a use case or through a separately funded project but with strong links to DestinE.

Although EO data is a critical input to DestinE it is only one of many sources, and so EO will not be the only focus of this development. The focus should be on the requirements of end users for long term.

Who

- **DG CONNECT** is responsible for DestinE and should be involved in any decisions on how to fund use cases. **DG ENER** and **DG RTD** are also relevant.
- **ECMWF** and **ESA** are between them responsible for the DestinE use cases, and could take on the oversight of the use case development.

Impact

- The key output is the availability of a long term demand and supply prediction model available to regulators and industry,
- Technical impacts include improved accuracy of the model outputs against currently used methods

Impact on	Low	Medium	High
Impact on **end users**		**Medium**	
Impact on **EO service providers**	**Low**		
Impact on **multipliers**			**High**
Impact on **governance actors**			**High**

6 Raw materials

Raw Materials, in this context, refer to the materials or substances used in the primary production or manufacturing of goods. It primarily encompasses the industry of **mining** or extracting "non-energy" commodities such as **minerals**, **rock**, or **metals**, and excludes the extraction of oil & gas as well as the management of forestry for wood.

Raw materials encapsulate a large array of primary input materials which play important roles in many sectors such as construction, chemicals, automotive, aerospace, machinery, pharmaceuticals, renewable energy devices, and defence. In the EU, these sectors have a combined added-value of around €1,000bn and provide employment for some 30 million people. There are many stages and sub-branches along and within the raw materials value chain, from **exploration**, to **extraction**, to **treatment**, to **transport** and **trade**. Each of these segments brings with them roles and processes which can be examined and improved through technological developments.

6.1 Where are we now?

The 2020 European Commission's Action Plan on Raw Materials contains 30 materials and charts out a plan towards greater security and sustainability of their supply. One of the ten proposed actions is to "**Deploy Earth-observation programs and remote sensing for resource exploration, operations and post-closure environmental management**". Furthermore, the 2021 United Nations Climate Change Conference (COP26) held in Glasgow highlighted the mining industry's integral role in supplying the metals and materials crucial for a low-carbon future[39]. Legislation and Environmental, Social, and Governance (ESG) expectations from governments, stakeholders and markets furthermore drive the trend of ambitious decarbonization and environmental targets for extraction companies.

The following policies and initiatives describe the overarching framework and direction in which the Raw Materials sector is being guided through international and governmental regulation.

Policy / Initiative	Description
United Nations Sustainable Development Goals (SDGs)	A 2016 report named "Mapping Mining to the Sustainable Development Goals" described how mining can help achieve several SDGs by: • Providing opportunities for employment • Creating of new business enterprises • Increasing fiscal revenues • Increase transport infrastructure development Moreover, it described how many of the minerals produced by mining are essential building blocks for technological components, infrastructure, energy, and agriculture.
Action Plan on Critical Raw Materials	• The EC has created a list of critical raw materials (CRMs) which is subject to a regular review and update. • CRMs combine raw materials of high importance to the EU economy and of high risk associated with their supply. • The 2020 list contains 30 materials and charts out a plan towards greater security and sustainability of their supply.

[39] https://www.forbes.com/sites/sap/2021/11/29/cop26-takeaways-renewables-replace-fossil-fuels-as-metals-become-a-major-force/

	• One of the ten proposed actions is to "**Deploy Earth-observation programs and remote sensing for resource exploration, operations and post-closure environmental management**"
European Innovation Partnership on Raw Materials (EIP)	• In 2008, the RMI stakeholder platform was initiated. • It brings together EU countries, companies, researchers, and NGOs to promote innovation in the raw materials sector. Its primary objective is to help to raise the Raw Materials industry contribution to the EU's GDP by securing its access to raw materials. • Its secondary objective is to play an important role in meeting the objectives of the Commission's flagship initiatives "Innovation Union" and "Resource Efficient Europe" by ensuring the sustainable supply of raw materials to the European economy whilst also increasing benefits for society as a whole.
EIT Raw Materials	• EIT Raw Materials is the largest consortium in the raw materials sector worldwide. • Its mission is to enable sustainable competitiveness of the European minerals, metals, and materials sector along the value chain by driving innovation, education, and entrepreneurship. • It unites more than 120 core and associate partners and 180+ project partners from leading industry, universities, and research institutions.
Raw Materials Initiative	In 2008 the EC adopted the RMI which set out a strategy for tackling the issue of access to raw materials in the EU. The strategy has 3 pillars which aim to ensure: • Fair and sustainable supply of raw materials from global markets • Sustainable supply of raw materials within the EU • Resource efficiency and supply of 'secondary raw materials' through recycling

Highlighted as one of the ten actions in the European Commission's Action Plan on Raw Materials, EO should be promoted and used in a variety of extraction activities. To bring context to this action, the below SWOT analysis covers the strengths, weakness, opportunities, and threats from the **viewpoint of EO data enabled services adoption by the raw materials sector**.

Strengths	Weaknesses
- Low-cost, large-scale, all-weather, day-night, continuous monitoring solution - Cost-effective compared to in-situ monitoring solutions	- EO-powered solutions not yet fit-for-purpose or turn-key - High cost-of-change barrier - Not yet integrating well with mining industry's workflows - Lack of procurement procedures with commonly accepted terms of reference - Lack of well communicated proven success stories of EO product applications

Opportunities	Threats
- Recent upstream advances (e.g. SAR constellations) enable larger role for EO data in mining safety monitoring - Increased digitalisation of mining operations - EO data can (at least partially) meet increased environmental monitoring requirements - Since mostly 'easy' mining deposits are exploited, miners need to go more remote and EO can provide cost-effective solutions for such remote sites - Very high demand for (critical) raw materials - Regulation/policy drivers	- General unawareness of the potential of EO services for mining - Lack of skilled personnel in EO technology at mining companies - Industry continued reliance on in-situ technology - Decreasing costs and increased ease-of-use of alternative solutions (e.g. UAVs)

On top of the points brought up previously, some general challenges seen across the raw materials industry include:

- **Environmental footprint:** Mining activities can have large carbon and environmental footprints; moreover, most raw materials are less than 1% recyclable; reducing these impacts is of vital importance for the sustainability of the sector.
- **Security of supply:** Many imported raw materials are vulnerable to supply shocks because of natural disasters or geo-political tensions.
- **Price volatility:** Market commodity prices constantly fluctuate, meaning trade flows and jobs can be put at risk.
- **Health and safety:** Mining is dangerous work; ensuring people remain safe is a constant challenge in the sector.
- **Access to energy:** Many mines are forced to operate in more and more remote locations. Connecting to a power grid is a major issue for many operators.
- **Perceived technological barriers:** Within the mining and raw materials sector, the use of cutting-edge technologies can sometimes be seen as only relevant for larger companies who can afford them.

Some of these challenges can be partly addressed by EO-enabled services, further elaborated on in section 6.2.

6.1.1 Market maturity

According to the EUSPA 2022 Market Report, the market size of EO data-enabled services for the raw materials segment is approximately €175m. EO services bring the most value in the selection, monitoring, and planning of mining sites (€103m). Environmental monitoring, considered a market segment on its own, also draws on EO powered solutions (€51m).

EO technology is thus used in the mining industry, and overall, maturity is improving. However, the EO sector does not yet offer truly fit-for-purpose, turn-key solutions for the mining industry, and the data products available on the market do not integrate well with the industry's workflows and systems. Moreover, the adoption of EO solutions comes together with a high cost-of-change barrier (as compared to the current way of working) that needs to be overcome. However, given the increasing demand for critical raw materials, but also the societal and environmental challenges related to mining, there is a growing need for EO solutions that can enable new exploration, planning, operations, and monitoring capabilities.

6.1.2 R&D trends

Various R&D trends have emerged related to the use of EO-data-powered solutions in the mining industry. Over ten years ago, the EO-MINERS project (2010-2013) aimed to bring into play EO-based methods and tools to facilitate and improve interaction between the mineral extractive industry and society in view of its sustainable development while improving its societal acceptability. Other foundational work was done by Deltares, an independent knowledge institute, and various supporting companies in the Earth Observation for Mining of Raw Materials (EO4RM) project that showcased its first results in 2020. Such projects focussed on **identifying key challenges of the mining industry and mapping and consolidating the relevant requirements** for various stages of the mining lifecycle, such as

- Exploration
- Environmental assessment & permitting
- Design, construction & operations
- Mine closure & aftercare

These projects also **highlighted how EO-data enabled services can help address some of the key challenges**. Such work is important to identify challenges and operational scenarios where EO data can play a supporting or even key role.

R&D trends furthermore **focus on the actual development of specific EO-powered operational services for the mining industry**, such as MOTIONMAPPER (2018-2021): a real-time slope stability and subsidence monitoring service to improve productivity and to prevent catastrophic events in the mining industry. In the field of logistics and supply chain monitoring, the ATTM project (2020) intended to enhance the transparency of local and global coal flows, highlighting logistic activities and coal volumetric changes in coal harbour areas using satellite-derived observations. Going beyond specific application development, the Goldeneye project (2020-2023) touches on data fusion and combination by building a data acquisition and processing platform. It aims to enable safe, sustainable, and cost-efficient mining operations by combining data produced by satellites, drones, and in-situ sensors to produce actionable intelligence.

Additional efforts also include capacity building. For instance, the RawMatCop Programme from EIT Raw Materials aims to develop skills, expertise, and applications of Copernicus data to the raw materials sector. It is for a large part funded by a series of grants from the European Commission (DG GROW).

Overall, the trends indicate various efforts to **understand the needs of the miners** followed by **activities to help develop relevant services, platforms,** and finally **develop the required capacities in the downstream segment.** Future actions to help develop this market segment should leverage and complement these existing efforts.

6.2 Where do we want to be?

6.2.1 Adoption of EO in low-hanging-fruit applications

In the next years, the following applications of earth observation are expected to become generally available and widely used, driven by the overall market trends, the specific needs of actors in the sector, and the advances in technological capabilities:

- **Large-scale geological mapping** to explore and select new **potential extraction sites**, including the assessment of terrain features and surface composition, specifically in bare ground situations in arid to semi-arid areas

- Comprehensive **monitoring of the environmental impact** of mining activities both at the mining site and in the surrounding area
- Monitoring and detection of **geological and hydrological changes to reduce safety risks**, in particular tailings dam and pit slope stability monitoring.
- Remote **stockpile measurements** to improve mining operations, and to enable material flow analysis for supply chain and market intelligence on a global scale.
- Use of satellite data in **permitting, licensing, and regulatory compliance processes**
- **Detection of illegal mining** activities based on satellite data

Prioritising the promotion and adoption of these applications could provide quick wins in the overall adoption of EO-powered services for the mining sector in the short term, as their development is relatively mature and has proven added value.

6.2.2 EO to help adhere to standards and regulations

Regulations and standards drive the uptake of EO-data powered services and solutions addressing environmental concerns that arise for mining operations. This includes pollution of air, soil, water, and noise, with potential negative impact on natural habitats, visual impact on the landscape and altering ground water levels.

- **Regulation: Mining Waste**
    - The mining waste stream is one of the largest in the EU, where some of it is dangerous. The EU legislative framework for managing mining waste safely comprises:
        - The Mining Waste Directive, introducing obligatory permits and setting requirements for building or modifying an extractive waste facility. If potential risk to the environment or public health exists, operators need to provide a financial guarantee and draw up emergency plans, a policy for prevention of major accidents, and develop safety management systems. **EO-data driven services can help with the fast identification of potential leakages or other events, required to enable a speedy response and can furthermore monitor site remediation efforts following an event and provide a historic baseline in support of further investigations into the cause of the event.**
        - The Seveso-III directive covers risks arising from storage and processing activities in mining, particularly tailing ponds and dams used in mineral processing of ores. **EO-data has been proven to help assess the stability of tailings dams over time and can be used as an early indicator of instability. SAR imagery is used furthermore to identify where exactly the waste changes on large sites have occurred. Subsequently optical imagery is acquired for the specific locations where changes have been documented.** Optical imagery allows for quantitative estimations of bulk material volumes and material classes.

- **Regulation: Water Protection**
    - Operational mines discharge poor quality water which impacts the environment, but also closed mines can leak contaminated water and should be monitored. Mine water is covered in the Water Framework Directive which introduces river-basin management and requires that a “good” status must be achieved for all EU water. It is furthermore complemented by the Groundwater Directive which sets quality standards for underground waters and introduces measures to prevent or limit the pollution of ground water.
    - It is a challenge to meet these needs with remote sensing data. **Remote sensing may indirectly address those issues by providing several indicators using gravimetry as well as interferometry**

techniques. **Satellite SAR data however is capable of accurately assessing the extent of surface water within a mining site as well as water gains and losses in a tailings dam, surface run-off, or any other water body within the area of interest**

Mining associations work together with international organisations and other stakeholders to develop standards that support the continual improvement in the safe and transparent management of mining activities.

- **Standard: Global Industry Standard on Tailings Management**
  - The United Nations Environment Programme (UNEP) together with Principles for Responsible Investment (PRI), a United Nations-supported international network of investors, closely cooperated with ICMM to create the Global Industry Standard on Tailings Management. This standard will drive the needs and requirements of miners that aim to implement the safety and monitoring standards outlined in this standard. EO has been proven to provide valuable insights for this activity. In addition to the standard, ICMM also developed a conformance protocol to help operators and independent third parties assess the implementation of the standard's requirements, and ultimately demonstrate conformance.

6.2.3 Increase high-GSD hyperspectral data availability

Hyperspectral remote sensing in the mining area has excellent demonstration effects[40], used to identify the likelihood of certain minerals being present at potential mining sites, from space. Currently, only a few hyperspectral payloads are in orbit. Developing hyperspectral sensors for small satellites, and launching several of them into orbit, can greatly increase the coverage and revisit potential of hyperspectral data around the globe.

The ground sampling distance (GSD) of hyperspectral sensors are rarely under 30 meters in the SWIR range (1000 to 2500 nm) and rarely less than 10 m in the VNIR range (400 to 1000 nm). The 2021 PRISMA workshop[41] showed that GSD was the limiting factor in the usefulness of hyperspectral data. Designing an instrument with a high GSD unavoidably leads to an instrument with a narrow swath, and thus the surface coverage is relatively small. Having many satellites, however, may compensate for this fact. The primary challenge in developing a multispectral instrument for small satellites is to achieve a useful spatial resolution in combination with acceptable signal-to-noise-ratio (SNR). Companies like HySpex are working on developing hyperspectral instruments for small satellites and the EU may consider supporting such developments to increase the earth's surface area mapped by high GSD hyperspectral instruments for mining exploration, and various other applications.

6.2.4 Increased capacity for miners to adopt EO-powered solutions

Most mining companies do not have the required EO expertise in-house to easily adopt EO-powered solutions into existing workflows. Specific capacity building programmes may be organised to boost the extractive companies' EO expertise to help implement EO solutions more easily into their day-to-day operations. Such efforts should exploit as much as possible the best practices and lessons learned from activities such as RawMatCop discussed earlier.

[40] https://www.nature.com/articles/s41598-020-79864-0
[41] https://www.planetek.it/eng/news_events/all_events/2021/04/hyperspectral_remote_sensing_workshop_2021_prisma_mission_and_beyond

6.2.5 Accelerate the availability and understanding of new technologies and data sources

Various new emerging technologies may have a potential impact on the mining industry, including:

- Multi-static SAR
- Satellite Video (e.g. NEMO-HD, launched 09/20)
- Passive Microwave
- Novel hyperspectral missions
- Digital twins

Furthermore, artificial intelligence and deep learning (pattern recognition, hybrid AI for complex analysis, super-resolution) will further accelerate the applicability of EO data for mining applications. Synergies are also foreseen with other data sources such as aerial data, high altitude pseudo-satellites, or crowdsourced data. Understanding, piloting and operationalising the associated applications will be therefore highly relevant for the raw materials segment.

6.3 How to get there?

6.3.1 Action RawMat 1: Promote ‘easy-win’ applications

Action number: RAWMAT_1

Timeframe

Short-term 1 – 2 years | Mid-term 2 – 5 years

Description

Various **EO-powered solutions are currently offered to the mining industry**, using different kinds of EO data, and **proven to work in many parts of the world**, yet **service providers continue to struggle with market adoption**, citing the traditional nature of the industry with high (perceived) changing costs. Thus, additional efforts are required to promote EO-powered solutions to the mining industry (tech companies) with an emphasis on potential financial and safety gains. Such efforts focussing on the promotion of ‘easy win’ applications can provide quick gains in the uptake of EO data in the mining industry.

How

i. Since the mining industry is traditional, direct ‘advertising’ or promoting of EO-powered solutions to miners may not be the most effective approach. Instead, it is essential to **target mining technology companies and incentivise them to expand their service offering with proven EO-powered products**. This allows the **leveraging of existing sales channels and tight-knit relationships** which the mining tech companies enjoy, as well as ‘speaking the same language’, **accelerating acceptance** and implementation of EO-powered solutions in the miner’s workflows.

ii. The applications selected for promotion could be the following:

   a. Large-scale geological mapping to explore and select new potential extraction sites, including the assessment of terrain features and surface composition, specifically in bare ground situations in arid to semi-arid areas
   b. Comprehensive monitoring of the environmental impact of mining activities both at the mining site and in the surrounding area
   c. Monitoring and detection of geological and hydrological changes to reduce safety risks, in particular tailings dam and pit slope stability monitoring.
   d. Remote stockpile measurements to improve mining operations, and to enable material flow analysis for supply chain and market intelligence on a global scale.
   e. Use of satellite data in permitting, licensing, and regulatory compliance processes
   f. Detection of illegal mining activities based on satellite data

iii. **Demonstrating use cases and financial successes of EO-powered solutions** in the mining industry is key to convince the mining tech companies to expand their service offering. Instead of inviting mining tech companies EU Space events, representatives of the EU Space Programme (could be EUSPA, FIRE evangelists, etc.) should **attend major mining conferences** (such as Resource Tomorrow, FT Mining Summit, etc.) and **demonstrate (financial/safety) success stories** (e.g. with dedicated booth). Secondary promotional activities can be done online through webinars. Service providers that provide (some of the) above applications will need to be identified and invited to demonstrate the use cases.

iv. Leveraging the dynamic built in FIRE and the Raw Materials Focus Group, it is essential to **foster the relationships between the service providers and mining tech company leads** that are generated during these promotional activities, by organising follow-up (online) workshops and events to ‘drive the story home’.

Who

- EUSPA

• Service providers (both individual companies and industry associations such as EARSC) • Major mining tech companies (e.g. ABB, IMDEX, MapTek, Modular Mining Systems)	
Impact • Increased availability of EO-powered solutions provided by mining technology companies • Increased uptake of EO-powered solutions by mining companies	Impact on **end users**: Low / Medium / **High** Impact on **EO service providers**: Low / Medium / **High** Impact on **multipliers**: **Low** / Medium / High Impact on **governance actors**: **Low** / Medium / High

6.3.2 Action RawMat 2: Help mining companies adhere to standards and regulations with EO solutions

<table>
<tr><td>Action number: RAWMAT_2</td><td rowspan="2">Timeframe

Short-term
1 – 2 years

Mid-term
2 – 5 years</td></tr>
<tr><td>Description

Environmental and safety standards/regulations are continuously evolving and are becoming more stringent, in some cases linked to tax advantages if they are complied with (or fines if they are not respected). EO-powered solutions that help miners adhere to regulations and standards are thus an 'easier sell', and these applications should be prioritised in the promotional efforts of the EU (DG GROW, EUSPA).</td></tr>
</table>

How

- **Identify applications that can help mining companies adhere to standards and regulations**
  - Tailings dams and pit slope stability monitoring (adhere to Seveso-III directive and global standard on tailings dam monitoring)
  - Monitoring of environmental impact (waste and water directives)
  - Monitoring of CO2 emissions (e.g., for coal plants)
  - Etc.
- **Obtain recognition and acknowledgement from the organisations that set industry standards** (e.g., ICMM) for the foreseen applications. Competent EU Agencies (e.g. EUSPA) could lobby for the **mentioning of EO-powered solutions in the conformity documentation** that such organisations produce to help miners adhere to the standards. A priority could be placed on the application of tailings dam monitoring: ICMM developed a **conformance protocol** to help operators and independent third parties **assess the implementation of the standard's requirements, and ultimately demonstrate conformance**. Having **EO-powered solutions explicitly mentioned in such documentation** would significantly boost their acceptance by mining companies.
- Promote their development and uptake by mining tech companies as part of their product offering to mining companies, in similar fashion as action RAWMAT_1

Who

- DG GROW (Raw Materials Unit)
- EUSPA
- EO service providers
- Mining associations (e.g., International Council on Mining and Metals) that set industry standards
- Major mining tech companies (e.g., ABB, IMDEX, MapTek, Modular Mining Systems)

Impact • Increased uptake of EO-powered solutions by mining companies that will help the adherence to regulations and standards	Impact on **end users** Low | Medium | **High** Impact on **EO service providers** Low | Medium | **High** Impact on **multipliers** Low | **Medium** | High Impact on **governance actors** **Low** | Medium | High

6.3.3 Action RawMat 3: Accelerate development of hyperspectral payloads and related applications

<table>
<tr><td>Action number: RAWMAT_3</td><td rowspan="2">Timeframe

Short-term
1 – 2 years

Mid-term
2 – 5 years</td></tr>
<tr><td>Description

The new technology trend of hyperspectral instruments (HSI) compatible with small satellite platforms provides significant potential for mining exploration applications. Supporting this specific technology development and deployment can accelerate the use of EO specifically in the reconnaissance and prospecting stages of the mine life cycle. In tandem, the downstream applications which leverage this type of data should be boosted.</td></tr>
<tr><td colspan="2">How

This should be pursued through the organisation of calls to (1) (co)finance the development of upstream hyperspectral payloads/sensors and (2) the development and operationalisation of downstream applications leveraging hyperspectral data.

• A first call may be issued to accelerate the hardware developments/demonstrations of HSI technology (potentially in combination with the Cassini In-Orbit Demonstration/Validation services). Such a call can be targeted by HSI instrument developers with proven flight-heritage (such as HySpex, Cosine, etc.)
• A second call may be issued to develop, or further refine, EO-powered mining applications which leverage the data coming down from existing (and upcoming) hyperspectral missions (e.g. GHGSat, EnMAP, CHIME, etc.), such as deep-earth exploration for rare earth minerals.</td></tr>
<tr><td colspan="2">Who (specific details on who should be involved)

• DG GROW (Raw Materials Unit)
• EUSPA and/or ESA
• Multispectral sensor developers for small satellites (e.g. HySpex, Cosine)
• EO Service Providers (Tre Altimira, GAF AG, etc.)</td></tr>
<tr><td>Impact

• Increased hyperspectral sensing capabilities in orbit to enhance EO-powered solutions for mineral exploration
• Further boost the currently largest application of EO in mining (raw materials site selection, planning)</td><td>Impact on end users
Low | Medium | High

Impact on EO service providers
Low | Medium | High

Impact on multipliers
Low | Medium | High

Impact on governance actors
Low | Medium | High</td></tr>
</table>

6.3.4 Action RawMat 4: Support Miners with Implementation of Specific Applications

Action number: RAWMAT_4

Timeframe

Short-term 1 – 2 years | Mid-term 2 – 5 years

Description

The adoption of EO-powered solutions by miners is **hindered by a lack of understanding**, both in terms of **potential improvements** in safety and/or cost effectiveness of operations, as well **how** such applications should be **implemented in existing workflows**. Capacity building efforts for miners can improve these understandings and accelerate the uptake of EO solutions in the industry.

How

- First, there is a need for **coordination with existing initiatives to build EO capacities for mining companies**, such as RawMatCop, to learn best practices and help assess the capacity building approach to avoid any major overlaps in materials and dates
- The capacity building approach should be adapted, based on the success of these existing initiatives, and serve as **complementary (implementation) support**. The approach could focus more on **assisting mining companies with the implementation of specific EO-solutions** in their workflows, taking note from success stories such as the one of Yara in Finland (using SAR data to assess pit mine slope stability, complemented by ground-based radars, to increase safety).
- Instead of providing certificates at the end of the course, more **application-specific results should be promoted** through statements such as: 'by end of this course: **guaranteed pit mine slope monitoring solution implemented in your mining operations workflow**, increasing safety standards in line with regulation XYZ'.

Who

- Existing capacity building initiatives such as those by RawMatCop and EITRM (along with its existing ecosystem of PhD students, Masters' students, industrial partners, and professionals within the raw materials sector)
- EO Service Providers
- Mining companies
- EUSPA

Impact

- Increased capacity of the mining industry to adopt and embrace EO-powered solutions in their mining operations workflows

Impact on **end users**		
Low	Medium	**High**

Impact on **EO service providers**		
Low	Medium	**High**

Impact on **multipliers**		
Low	Medium	High

Impact on **governance actors**		
Low	Medium	High

6.3.5 Action RawMat 5: Monitor and Inform the Mining Industry of Relevant New (EO) Technologies

<table>
<tr><td>Action number: RAWMAT_5</td><td rowspan="2">Timeframe

Short-term
1 – 2 years

Mid-term
2 – 5 years</td></tr>
<tr><td>Description

Various technology trends in EO have direct impact on the suitability of EO-powered solutions to address the needs of the raw materials segment. Through this action the aim is to accelerate the availability and understanding of new technologies and data sources relevant to the mining industry (and its service providers) by continuously monitoring these (while highlighting prototype success stories) and reporting on them in a (half)yearly cadence.</td></tr>
<tr><td colspan="2">How
EUSPA may monitor recent and upcoming emerging technologies (Multi-static SAR, Satellite Video, Passive Microwave, Novel hyperspectral missions) and assess their relevance to specific applications in the mining life cycle.
Produce (half)yearly insights (report) on operational new technologies with showcase of successes (prototypes, operational implementation, etc.)
Feed results into the aforementioned actions RawMat 1 to RawMat 4.</td></tr>
<tr><td colspan="2">Who
EUSPA</td></tr>
<tr><td>Impact
Accelerated uptake of new technologies by EO service providers relevant to applications in the mining industry</td><td>Impact on end users: Low | Medium | High

Impact on EO service providers: Low | Medium | High

Impact on multipliers: Low | Medium | High

Impact on governance actors: Low | Medium | High</td></tr>
</table>

7 Infrastructure

7.1 Where are we know?

Physical networks of roads and railway including bridges and tunnels are an important backbone of industry and society, as they enable mobility of citizens and transportation of goods. They are thus contributing to economic growth and employment (the transport industry in Europe employs 1om people and accounts for 5% of the GDP) as well as to quality of life. The European single market demands such infrastructure for free movement of goods, integrating all regions. The EU28 counts a combined 218k km length of railway lines (2018), 77k km of motorways (2017), all roads combined 4.85mn km (2013). Not only building these has been a massive investment over time, also their maintenance – crucial for safety and availability. Transport infrastructure investment across EU28 countries in 2018 exceeded €100bn, maintenance on overage €25bn per year during 2010-2014. It is in particular in planning and maintenance where Earth Observation – remote sensing or in situ measurements – already plays an important role.

Beyond transportation infrastructure, pipelines are critical infrastructure that need surveying and monitoring throughout planning, construction, and service life. They may be used for long-distance transportation of e.g. oil or gas, but also inside cities for e.g. gas, water, or sewage. Maintenance of these large and often difficult to access structures is a major effort and crucial to reduce downtime, which can have significant impact on economy and quality of life.

There are several policies shaping the overarching framework for infrastructure related activities. These are driven by three key aspects (i) **sustainability** for the reduction of the environmental impact of infrastructure – especially with regard to the construction phase which requires important amount of raw material and energy while creating lots of waste; (ii) **connecting EU transportation networks** towards increased economic performance of our societies; and (iii) **safety** on transportation networks. The table below illustrates some of the most important policies.

Policy / Initiative	**Description**
The European Green Deal	Achieving the goal of neutrality by 2050 will require a wide range of actions that reduce the environmental footprint of infrastructure and strengthen its climate resilience. There is also an important impact for the rail industry as the European Commission recognises the benefits of rail as a sustainable, smart and safe means of transport, putting rail in the spotlight.
United Nations Sustainable Development Goals (SDGs)	• **SDG9: Industry, innovation and infrastructure:** infrastructure contributing to an economic environment that generates employment and income • **SDG11: Sustainable cities and communities:** roads and transport systems as one crucial factor for quality of life and environmental sustainability; protection of and safeguarding the world's cultural (and natural) heritage is a further target
Trans-European Transport Network (TEN-T)	TEN-T policy addresses the implementation and development of a Europe-wide network of railway lines, roads, inland waterways, maritime shipping routes, ports, airports and railroad terminals. The ultimate objective is to close gaps, remove bottlenecks and technical barriers, as well as to strengthen social, economic and territorial cohesion in the EU.
The Connecting Europe Facility (CEF)	CFE is a key EU funding instrument to promote growth, jobs and competitiveness through targeted infrastructure investment at European level. It supports the

	development of high performing, sustainable and efficiently interconnected trans-European networks in the fields of transport, energy and digital services. CEF investments fill the missing links in Europe's energy, transport and digital backbone.
Directive 2004/54/EC on minimum safety requirements for tunnels in the Trans-European Road Network	Proposed actions to guarantee a high, uniform, and constant level of security, service, and comfort on the Trans-European Road Network
EU Road Safety Policy Framework 2021-2030 - Next steps towards "Vision Zero"	• The Safe System includes demands for safer and improved infrastructure • Properly maintained roads are believed to reduce the probability of road traffic accidents

EO can support many of these policies and infrastructure development in general in relation to improving compliance, monitoring the environmental impact, reducing risks and supporting the planning and designing phases of new infrastructures.

EO is also extremely useful in avoiding repairs and remediation costs thanks to ground movement maps which guide the planning and the preventative maintenance of infrastructure. More specifically, **Interferometric Synthetic-Aperture Radar (InSAR)** technology is unique in what it can offer to the management of roads (including tunnels and bridges), railways, pipelines and construction sites. Below is a SWOT analysis representing it EO possibilities and limitations with regards to infrastructure.

Strengths	**Weaknesses**
EO and especially InSAR technology is a key tool for infrastructure designers and engineers. It offers important monitoring advantages: - Good revisit time - Low-cost access to Sentinels data compared to in-situ monitoring solutions - Possibility to detect vertical ground movements with millimetre precision. - Possibility to have access to historic data to establish long-term ground movement trends.	Barriers exist for potential users to implement a switch: - High cost-of-change barrier - EO services are not yet integrating well with infrastructures industry's workflows - Lack of well communicated proven success stories of EO product applications. - The asset owner (either public or private) makes the decisions about the implementation of new technologies based on the available budget. - Cybersecurity of sensitive data of critical infrastructure (e.g. tunnels, bridges, pipelines, nuclear power plants, etc.) - Infrastructure companies need to have a clear view on the full business case, including costs and savings, before getting started. Additional technical issues may turn potential users to be reluctant to use InSAR for ground monitoring: - Revisit rate and resolution for specific applications are too low (when using only Sentinels), e.g. to locate the sources of ground movement.

	- Satellites are subject to possible defects. E.g. Sentinel 1-B is not operational anymore and revisit time is therefore hindered until Sentinel 1-C will be launched.
Opportunities - Upstream advances will improve revisit rate and resolution. E.g new Sentinel 1-C will be more powerful and integration of existing SAR constellations with the new planned commercial constellations will increase both the resolution and the revisit times. - Increased digitalisation of planning and running infrastructures operations. - EO data can (at least partially) meet increased environmental monitoring requirements. - Wave of digital transformation through the sector will create opportunities	**Threats** - General unawareness of the potential of EO services for infrastructure. - Lack of skilled personnel in EO technology at infrastructure companies. - Industry continued reliance on in-situ technology. - Decreasing costs and increased ease-of-use of complementary solutions (drones)

General challenges seen across the infrastructure industry include:

- Environmental footprint created by construction and use of infrastructure
- Increasing interconnection and interdependence of infrastructure systems
- Capacity limits due to growing population and strained economy
- Lack of detailed data on location and condition of legacy infrastructure
- Availability of land and space for new infrastructure
- Maintenance of large networks, including in remote areas

Some of these challenges can be partly addressed by EO-enabled services, further elaborated on in section 6.2.

7.1.1 Market maturity

The use of EO data is progressively penetrating all infrastructure management activities at all stages of the infrastructure life cycle. From the initial site selection and planning to the assessment of infrastructure environmental impact and the regular monitoring of construction operations, the increasing exploitation of EO-based information brings solutions to an ever-growing user base in the infrastructure management area.

Today, the **Interferometric Synthetic-Aperture Radar (InSAR)** technology - relying, amongst others, on Sentinel 1 since 2014 - has proven to offer reliable and useful information in a wide range of applications, including monitoring the movement of tunnels, roads, bridges and pipelines, or the displacement of dams to a precision of millimetres (with a possibility to obtain historical data). Such large-scale, historical and precise information cannot be obtained by in-situ techniques which makes it a key tool for infrastructure designers and engineers. It can thus offer support across the design, construction and operational phases of infrastructure projects; from gaining insights into historic ground conditions, to monitoring the settlement of foundations.

Europe has world-leading capabilities in Synthetic Aperture Radar, both upstream (i.e. constellations such as Cosmo-SkyMed, TerraSAR-X or more recently ICEYE) and downstream (i.e. companies such as eGEOS, TRE-

ALTAMIRA or DARES). Europe also has a long tradition in complex infrastructure and engineering projects whereby ground deformation must be monitored before, during and after the construction phase. Copernicus S1 has further revolutionised the provision of services such as INSAR for infrastructure-related applications, enabling viable business models for the companies involved. In this context, a number of public authorities across Europe have already adopted InSAR solutions powered by Copernicus Sentinel-1 for such purposes. This uptake is also reflected both at EU level, with the recently launched European Ground Motion Service of Copernicus, and at Member State level (in Germany, Italy, Spain and France), with the roll out of regional or nationwide InSAR services. Finally, the number of currently deployed private satellite constellations with high-resolution SAR capabilities is increasing.

On the other hand, **optical imagery** - provided, amongst others, by Sentinel 2 since 2015 - has proven to be efficient in supporting change detection in land cover and vegetation. It supports fewer (than InSAR technology), but still significant, applications with regards to infrastructure. These applications are mainly related to monitoring the environmental impact of infrastructure and to monitoring vegetation impeding operations on transportation networks and especially railways. The maintenance of railway infrastructure is essential to ensure the safety, efficiency, availability and reliability of railway operations. Defects on tracks, catenary or signalling infrastructure can lead to traffic interruption or even derailments and accidents. In this regard, only few railway companies in the EU (e.g. SNCF or Deutsche Bahn) are taking advantage of high-resolution optical Earth-imaging satellites, such as Pleiades, to improve vegetation monitoring at lower costs. One of the best known start-ups actively developing railway applications for EO is the Berlin based company LiveEO. The application allows the Deutsche Bahn to map and track the growth of vegetation around railways and informs where fallen trees are blocking the railway tracks.

According to the EUSPA Market Report, the revenues from the sales of EO data and services to the infrastructure sector represented €192m worldwide in 2020. The three largest application domains in terms of market shares (with a cumulative total of 66%) being, respectively site selection and planning, environmental impact assessment of infrastructure, post-construction operations.

Zooming in to individual cases, the Sentinel Benefits Analysis (studies performed by EARSC and Evenflow) illustrates well the added value of EO on **road** infrastructure monitoring and on **pipeline** monitoring

- In Italy, a ground motion service based on Satellite technology using data from Europe's Sentinel 1 satellites, is being used by the Italian Road Authority (ANAS) since 2017 to help detect and monitor unstable ground. Time and money saved through avoiding re-engineering works or delays to projects are considered to lead to economic benefits of between **€9m to €14m per year**.
- In Norway, ground motion mapping using Sentinel-1 data was implemented in 2014. Its economic benefits are estimated between **€3.8m and €8.7m per year** for the management of road infrastructure.
- In the Netherlands, ground subsidence (1m within a few years) can cause gas and water pipelines to break. Satellite images, which are used since 2014 in the Netherlands, can show hot spots where ground movement is taking place and can provide for a targeted maintenance strategy. In this regard, EO added value is estimated at **€15.2m to €18.3m per year**.

Currently, there is a clear demand from and towards the infrastructure sector for more and better satellite-based solutions that help to reduce uncertainties and risks, achieve environmental and climate goals, and increase operational efficiency. In this framework, the Sentinel Benefits Analysis (cited above) also demonstrated infrastructure stakeholders' needs and preparedness to adopt EO-based solutions e.g Sentinels are shown to be insufficient to locate the source of ground movement or to detect pipelines leaks and other disruptions.

Although the level of uptake of EO-based solutions is growing, it is still at an early stage. This has been recently recognised at member state level (with several launching their own nationwide INSAR services) but also at EU level with the roll out of the European Ground Motion Service being supervised by EEA. Next to such technical developments though, there is a significant need for market development support, engagement of actors that can become champions for the adoption of EO, and replication of best practices. These needs have also been acknowledged by the EC. According to the EC's Staff Working Document on the Expression of User Needs for the Copernicus Programme, *"Knowledge on land use and land use change is of primary importance to support many regulations for which the use of land has to be known, reported and even planned [...]"* and a *"[...] reference mapping of the land use is thus necessary to support many policies [...]"*. The document further states that rail and inland transport *"are currently less addressed by Copernicus products"*.

7.1.2 R&D trends

The development of EO data and services in the infrastructure sector has been supported by R&D&I efforts in the **generation of the products,** their **use in different and more complex situations** and **the uptake of the services** (on the demand side)**.**

Regarding the **generation of the products**, future improvements lie in the emergence of low-cost small satellite technology and the launch of sentinel 1-C (to replace sentinel 1-B)[42]. Whereas sentinel 1-C is more powerful than its predecessor, the integration of existing SAR constellations like Sentinel-1 with the new planned commercial constellations will increase both the resolution and the revisit times. Many acquisitions will open the possibility to providing semi real-time monitoring that could be very useful during extreme-meteorological events, for faster response and for semi-real time failure-prediction purposes. Thus, this technology will benefit certain applications such as construction monitoring, asset monitoring, vegetation monitoring, source of movement identification and environmental impact monitoring which require optical and/or radar imagery with higher revisit rates and higher resolution.

Several recent and ongoing R&D projects focus on the **use of EO in different and more complex situations**. The recent European project MOMPA (2021), for example, focuses on an early detection of movements in the Eastern Pyrenees (Mechanisms to transfer the results to other regions and contexts are also identified). It allows an assessment of the risk associated with active phenomena that affect structures and infrastructures. This cross-border project provides the expertise of four international partners, which are specialized in remote sensing and techniques of risk analysis and management. GATHERS, another R&D collaborative project (within H2020) focuses on the integration of Geodetic and imaging techniques for monitoring and modelling the Earth's surface deformations and Seismic risk. The overall objective of GATHERS is to enlarge the number of research-intensive sections at the Institute of Geodesy and Geoinformatics of The Wrocław University of Environmental and Life Sciences (UPWr) and to establish strong networks with the most outstanding Universities of geospatial sciences in Europe. A third R&D project is MotionMapper which is also part of H2020. It focuses on a real-time ground motion disaster mitigation system based on satellite, drone and ground radar images for industry (Mining, Construction and Oil & Gas Industries) safety and efficiency. Another project under H2020, is PANOPTIS. It aims to improve the resilience of road infrastructure and ensure reliable network availability under unfavourable conditions, such as extreme weather, landslides and earthquakes. Regarding Railways, ASSETS4RAIL is exploring, adapting, and testing cutting-edge technologies for railway asset monitoring and maintenance, including bridges and tunnels, as well as track geometry. More generally, the Copernicus Climate Change Service (C3S) provides trustworthy and traceable climate information (past, current and future) on how extreme events and weather patterns impact infrastructure in Europe and worldwide.

Additional industrial R&D projects are carried out to study the potential for wide operational deployment of satellite-based synthetic aperture radar interferometry (InSAR) or LiDAR acquisition by drones. This application could be used to detect subsidence and monitor landslide risks over large areas with centimetre-level precision. This technology could be used as a complementary source of information to satellite observation.

Other projects focus more on the **uptake of the services**. **CAMEO**, a project funded by the European Space Agency under the EO science for society activity, has sought to boost the understanding and integration of satellite EO services by companies and agencies managing pipeline and energy transmission corridors.

[42] https://www.esa.int/Applications/Observing_the_Earth/Copernicus/Sentinel-1/Ride_into_orbit_secured_for_Sentinel-1C

Additionally, important accelerators of R&D, innovation and user uptake are **trainings** on the specific use of EO data. These trainings allow researchers and other users of LiDAR, GNSS and InSAR to improve and share their knowledge while expanding their network. For example, GATHERS (cited above) organised a summer school on theoretical and practical aspects in surface deformation monitoring. Oikon, a leading licensed and accredited consulting company / research institute in the field of applied ecology in Croatia and the region organised a summer school where participants had the opportunity to hear and learn from top international professors and researchers about different applications of remote sensing using UAV (drone), LiDAR sensors, SAR and various software for processing collected data, with specific examples and practical tasks.

7.2 Where do we want to be?

7.2.1 Adoption of EO in established applications

In the next years, the following applications of earth observation are expected to become generally available and widely used, driven by the overall market trends, the specific needs of actors in the sector, and the advances in technological capabilities:

- **Large-scale ground movement mapping** with large archives of data (with the needed storage capacity to analyse sites retrospectively). It is proven to be extremely useful for various applications such as for **planning infrastructure** construction to avoid unstable areas and for detecting and **monitoring geohazards** across thousands of kilometres of pipeline, roads, railways, energy networks, etc.
- EO can support the evaluations to be carried out for **delivering permits and assessing environmental impact** of infrastructure construction activities both at the construction site and in the surrounding area. To that end, land cover/land use mapping, forest mapping, geological evaluation, exposure to natural disasters (e.g., floods) and ground deformation are used.
- Detecting **encroaching vegetation on roads and railways**. Among the potential railway applications of EO, vegetation supervision is currently the most industrialised. For the last two years, some railway operators, such as SNCF or Deutsche Bahn, have been using very high-resolution optical Earth-imaging satellites to get large amounts of information on vegetation development along tracks. This data is used to assist vegetation management teams to operate more efficiently. This application can surely be extended to other operators.

Prioritising the promotion and adoption of these applications could provide quick wins in the overall adoption of EO-powered services for the infrastructure sector in the short term, as their development is relatively mature and have proven added value.

7.2.2 EO to help adhere to standards and regulations

EO helps address important challenges linked to regulations, especially regarding **sustainability**, **EU transportation network** and **safety** on transportation networks.

With regards to **sustainability**, EO helps in assessing the environmental impact of infrastructures. EO can support the analysis of the impact of existing infrastructures (including during the construction phase) on the environment and ecosystem in their surroundings. Relevant EO-based products and services include pollution monitoring (air, water, soil), vegetation and biodiversity monitoring, etc.[43] Satellite imagery can also help to monitor the status and

[43] Source: EUSPA Market Report - https://www.euspa.europa.eu/2022-market-report

extend the life of critical infrastructure, detect illegal building collapse, monitor the stability and structural integrity of infrastructure, empower local residents to safeguard green and blue open spaces, green buildings services such as optimising energy consumption, urban planning, etc.

A particularly interesting case is the development of climate (change)-resilient infrastructure (promoted by SDG9). Due to climate change, infrastructures will be increasingly exposed to unfavourable conditions, such as extreme weather. The PANOPTIS project promotes the use of EO data by civil engineers (and other stakeholders) to build infrastructure in a more resilient way which improve the life span of infrastructures. This is a direction that needs to be further explored and supported towards maturation.

To better connect **European Transportation Networks**, EO serves in the planning of new roads, railways, tunnels and bridges.

To ensure **safety** on roads and railways, EO serves in preventing risks associated with ground movements and fires. In Portugal, for example, EO is already used to manage vegetation growth along roads in compliance with fire risk management regulation. Widespread adoption of such practices should be pursued. For this though to be accelerated further work on the relevant regulation is required. At present, the actors involved in activities that may cause subsidence are typically obliged to monitor their operations only at a small radius around where they work (e.g. metro tunnels). Often, however, these activities cause damages to buildings much further away. For such cases, InSAR is the only technology that can establish causality. Ensuring that EO-based approaches are explicitly mentioned in relevant regulation at EU or national level, will further open up market opportunities for EO companies.

7.2.3 Develop new applications/markets for EO solutions in Infrastructure

R&D is currently focussing on many (potential) new applications that can be further developed and marketed. A first example **is water leaks,** which are an important problem found in nearly every pipeline system in the world. The use of near infrared satellite imagery can highlight areas of high moisture vegetation near water pipelines and hence helps in detecting leaks.

Moreover, InSAR has the ability to monitor subtle movements of all **dams**. Monitoring dams regularly could therefore help in preventing disasters by detecting ground subsidence at an early stage.

The potential to better monitor critical infrastructure such as **bridges and tunnels** appears to be strong; but will require commercial data since the spatial resolution of Sentinel-1 is insufficient to locate the sources of movement. This is also true for litigation where the source of the movement will need to be identified. In the near future, this gap will be increasingly filled by commercial constellations of Earth Observation satellites.

7.2.4 Increase EO capabilities of infrastructure engineers and operators

Whilst several champions of EO solutions in support of infrastructure exist, the average stakeholder involved in infrastructure projects is not well-aware of the full breadth of EO capabilities and often, more importantly, operationally capable to adopt EO solutions in their workflows. Therefore, more effort should be placed in training as many infrastructure development companies as possible towards adopting EO-powered solutions into existing workflows. To that end, specific capacity building programmes may be organised to boost EO expertise to help implement EO solutions more easily into their day-to-day operations.

7.2.5 Make Copernicus data access and understanding trivial

For a smooth uptake of the EO-based services, the access to EO data that can be leveraged for infrastructure must be trivial. Specifically, all data access and analytics - especially ground movement mapping at large scale - should be migrated to cloud-based platforms. The data should furthermore be organised and released in data cubes and other forms of Analysis-Ready-Data. And lastly, effective and well-understood state-of-the-art AI should be linked to these datasets to enable the production of actionable insights relevant to the infrastructure sector. All these aspects become all the more relevant given the strong push for digitalisation of Infrastructure.

7.2.6 Accelerate the availability and understanding of new technologies and data sources

Various emerging technologies may have a potential impact on the infrastructure industry. This includes multi-static SAR, satellite Video (e.g. NEMO-HD, launched 09/20), passive microwave, novel hyperspectral missions and digital twins. Moreover, the launch of a large numbers of smaller satellites (“smallsats”) in recent years has boosted the capabilities of EO as a whole, providing higher and higher spatial and temporal resolution data.

In parallel, various AI/data driven applications are also emerging and should, as well, have an impact on the uptake of EO services for infrastructure. This includes advances in digital elevation models, geophysical and soil characteristics for civil engineering related to networks deployment, real-time monitoring and long-time records of known sites affected by ground motion or natural risks, as well as climate records describing frequency and intensity of seasonal weather events for climate vulnerability and risk assessments.

Developing solutions that leverage such new capabilities and paradigms would be an important step towards the modernisation of practices in the infrastructure sector and, eventually, the uptake of EO solutions.

7.3 How to get there?

7.3.1 Action INFRA 1: Widespread uptake of ground movement mapping

Action number: INFRA_01

Timeframe

Short-term
1 – 2 years

Mid-term
2 – 5 years

Description

Having proven their unique value in several operational scenarios, InSAR-based solutions supporting different stages of the infrastructure development should be widely adopted by relevant stakeholders. This should rely on Europe's world-leading capabilities in InSAR (both in terms of hardware, i.e. satellites but also software, i.e. algorithms, automated processing chains, etc.). And it should take stock of the increasing need to build and maintain sustainable, smart infrastructure.

To that end, a multi-faceted approach should be followed with the aim to widen demand and strengthen supply of InSAR solutions. Thus, next to technical developments on the supply side, there is a significant need for market development support, engagement of actors, and replication of best practices.

How

On the **Supply side**, there is a need to improve the service offering by supporting large-scale ground movement mapping with large archives of data involving important **storage capacity** (cloud computing is key for accessibility and fast results). Currently, data is collected at specific places of need. Gathering large scale EO data blended with **local data** while implementing/using powerful **AI tools** will allow to prevent many risks associated with ground movement. The mapping can also be improved and complemented by non-EO data (e.g. drones carrying InSar technology) and by new privately-owned smaller satellites ("smallsats").

On the **Demand side**, user uptake could be well improved by **engaging R&D stakeholders' communities** to (a) understand their needs, (b) present EU capabilities that match them. The European Construction, built environment and energy efficient building Technology Platform (ECTP) would be a good candidate to start with. It is a membership organisation and one of the European Technology Platforms which aims to promote and influence the future built environment through innovation-related activities. Being active along the infrastructure value chain, focused on innovation and digitalisation, and well connected to the sector as well as many European initiatives and programmes, ECTP appears to be a valuable player through which space-enabled solutions could be integrated in research, innovation, development, and eventually planning, construction, and monitoring of the built environment. Creating other opportunities to bring together pioneer users, less experimented users (or potential users) with InSAR service providers will also be useful. For example, a recent Sentinel Benefits Analysis Workshop on road infrastructures bringing various stakeholders together allowed (potential) users to **discover additional applications of EO**.

Moreover, a **handbook on InSAR technology,** the equivalent of the BIM Handbook, could also be considered – i.e. the INSAR Handbook, in cooperation with DG GROW and DG MOVE**.** It could provide an in-depth understanding of InSAR technologies, the business and organizational issues associated with its implementation, and the profound advantages that effective use of InSAR can provide to all members of a project team.

Last but not least, EU competent authorities should explore the possibility to **push services by the EU Space Programmes in EU or national regulation**. The key here is that companies involved in the construction of tunnels, roads, etc. would be obliged/encouraged to observe subsidence phenomena associated with their work using INSAR. At present, the actors involved in activities that may cause subsidence are typically obliged to monitor their operations only at a small radius around where they work (e.g. metro tunnels). Often, however, these activities cause damages to buildings much further away. For such cases, INSAR is the only technology that can establish causality. Ensuring that EO-based approaches are explicitly mentioned in relevant regulation at EU or national level, will further open up market opportunities for EO companies. All these aspects shall form part of a multi-faceted action to create markets for INSAR.

Who

- EU competent authorities such as EUSPA, DG GROW (responsible for construction) and DG MOVE (responsible for transport networks)
- Key account candidates identified above.

Impact

- Increased awareness on INSAR technologies and latest R&D developments for infrastructure projects
- Increased adoption of INSAR technologies, by infrastructure managers and construction companies

Impact on **end users**		
Low	Medium	**High**

Impact on **EO service providers**		
Low	Medium	**High**

Impact on **multipliers**		
Low	**Medium**	High

Impact on **governance actors**		
Low	**Medium**	High

7.3.2 Action INFRA 2: PCP for road and railway operators

Action number: INFRA_02

Timeframe

Short-term
1 – 2 years

Mid-term
2 – 5 years

What

EO is being used for vulnerability analyses and exposure assessments of critical infrastructure in the road and rail domains. This is connected to vegetation monitoring (or identification of other obstacles/disruptions) with, for instance, major railway operators using services that leverage VHR to monitor the condition of their infrastructure. Similarly, as previously described, road management authorities are monitoring ground displacement affecting the road network they manage.

Despite such instances, the utilisation of EO services in such operational scenarios is far from widespread. The objective of this action is to **expand the use of these services to other operators through the EU**.

How

The focus of this action should be on the setup and implementation of **market pull mechanisms** that could accelerate and enlarge the uptake of EO-based solutions for road infrastructure managers and railway operators. The proposed approach is to organise a dedicated Horizon Europe call focussing on **pre-commercial procurement** for such stakeholders. This would require a few preparatory steps to ensure maximum impact. Firstly, a **gap analysis** should be performed (e.g. through dedicated study funded by EC or associated agencies) assessing the extent to which current and evolving user needs can be met by EO-based solutions and what types of improvements (in terms of R&D) need to be carried out. Secondly, stakeholders that may become part of the group of procurers should be engaged in **dedicated workshop** to ensure that (i) their operational realities, procurement, legal and regulatory constraints are captured, (ii) they are aware and agreeable to the possibility of adopting EO-based solutions in their workflows. This part should be animated through the participation of existing champions (who could also end up becoming lead procurers). The call itself should follow best practices in accordance with the *Guidance for Innovation Procurement from the European Commission* as well as relevant lessons learnt from EO-related PCPs (e.g. Marine-EO). Particular attention during the formulation (in terms of requirements) and implementation (monitoring of tasks) of the call should be placed on (i) the technological/innovation steps required for service providers to develop solutions that address needs formulated by the group of buyers in the Innovation Procurement (taking into account underlying infrastructure, value chain linkages, data availability, etc.); (ii) the development of appropriate business models to suit the operations of road management authorities and railway operators and ensure sustainable provision of valuable services against their needs, so that after the end of the PCP project sustainable use of the EO services ensues.

Who

- EU competent authorities such as EUSPA
- Rail and road operators already working with EO data such as SNCF, DB and BRISA (highway operator in Portugal)
- EO service providers already working within the rail segment such as LiveEO, e-GEOS and Gamma Remote Sensing – broad participation should be promoted through EARSC
- CER: brings together more than 70 railway undertakings and national associations, contributing to a wide user base and an extensive, representative network of railway undertakings. A clear, convincing and attractive communication will help trigger member’s interest, as they are largely unconcerned with the topic of EO.

Impact • More road and rail companies and organisations engaged in the process. • Increased operational adoption of EO solutions in road and railway infrastructure monitoring	Impact on **end users**: Low / Medium / **High** Impact on **EO service providers**: Low / Medium / **High** Impact on **multipliers**: Low / **Medium** / High Impact on **governance actors**: Low / **Medium** / High

,

7.3.3 Action INFRA 3: EO to develop climate change resilient infrastructures

Action number: INFRA_03

Timeframe

Short-term 1 – 2 years | Mid-term 2 – 5 years

What

Due to climate change, infrastructures are increasingly exposed to unfavourable conditions, such as extreme weather. Additionally circular economy is getting important in the construction sector which triggers the need to improve the lifespan of infrastructure. Recent projects (e.g. PANOPTIS) have shown the potential of EO solutions at improving the resiliency of the road infrastructures and ensuring reliable network availability under unfavourable conditions. Moreover, the Copernicus Climate Change Service (C3S) has been providing trustworthy and traceable climate information (past, current and future) on **how extreme events and weather patterns impact infrastructure in Europe and worldwide.** Further R&D is required with the involvement of relevant stakeholders on both demand and supply sides for such solutions to reach adequate operational maturity.

How

By launching a dedicated RIA call or equivalent (e.g. Copernicus Demonstrators by EUSPA, ESA's Expand Demand), the EC and its partners could help the operationalisation of EO-based solutions focussing on climate vulnerability and climate resilience of (critical) infrastructures. Whilst some synergies with the previous action can be foreseen, the key here is to engage both collaboration between academia and industry in developing appropriate downstream solutions (leveraging observational capabilities and AI/ML approaches) to serve the needs of end users in different operational scenarios.

Who

- Infrastructure end-users
- EO Industry (through EARSC)
- Multipliers (e.g. ECTP)

Impact

- Increased awareness on EO benefits for Infrastructure sector actors
- Increased adoption of EO solutions by Infrastructure sector

Impact on	Low	Medium	High
Impact on **end users**	Low	**Medium**	High
Impact on **EO service providers**	Low	**Medium**	High
Impact on **multipliers**	**Low**	Medium	High
Impact on **governance actors**	Low	Medium	**High**

7.3.4 Action INFRA 4: Incorporate EO in regulation driving large-scale infrastructure projects

Action number: INFRA_04

Timeframe

Short-term 1 – 2 years | Mid-term 2 – 5 years

What

The Trans-European Transport Network policy aims to build an effective EU-wide transport infrastructure network. This is realised through the mobilisation of resources supplied by the European Regional Development Fund (ERDF), the Connecting Europe Facility and the European Fund for Strategic Investment (EFSI). At present there is practically no provision in the associated regulation on the utilisation of Copernicus (or EO)-enabled solutions for different stages of infrastructure development that is funded under these programmes. This constitutes a missed opportunity for market development and associated benefits resulting from EO solutions.

How

The aim of this action would be to **develop a comprehensive roadmap for the incorporation of EO in relevant regulation**. This entails a thorough analysis of the current state of play both in terms of regulatory provisions and in terms of practices at Member State level. In such a stakeholder consultation and analysis, the involvement of the Copernicus User Forum and the coordination by EUSPA (as designated market development agency) could be key. Any updates in relevant documentation (e.g. Staff Working Documents or Strategies) by the competent EC DGs should also be informed. Relevant success stories should be disseminated not only through the Copernicus-related media but most importantly through the sectorial ones. Long-term awareness raising and capacity building would also be necessary as would a linkage with the outputs of R&D or commercialisation efforts described in the previous actions.

Who

- Competent EC DGs (GROW, MOVE)
- EUSPA

Impact

- Creation of appropriate framework conditions that accelerate uptake of EO
- Increased adoption of EO solutions by Infrastructure sector
- Increased awareness on EO benefits for Infrastructure sector actors

Impact on	Low	Medium	High
end users		**Medium**	
EO service providers		**Medium**	
multipliers		**Medium**	
governance actors			**High**

8 Cross-cutting Actions

The previous sections have laid out actions under each one of the six sectors covered in FIRE. Most of these actions are specific to the sector; nonetheless, several of these actions follow common patterns e.g. incorporation of EO in sector-specific policy and regulation, capacity building activities, wider uptake of EO in established or new applications in a given sector. On top of all these sector-specific actions we propose a few cross-cutting actions.

8.1.1 Sustainable support to and expansion of focus groups

<table>
<tr><td>Action number: CROSS_01</td><td rowspan="2">Timeframe

Short-term 1 – 2 years
Mid-term 2 – 5 years</td></tr>
<tr><td>What

FIRE has pioneered the establishment of Focus Groups as a means to engage sectorial actors as potential users of EO services. So-called Sector Leads, (mostly member-based) organisations representing the respective sector well, have been approached to benefit from both their expertise in that sector and knowledge about challenges, as well as from their network of stakeholders across value chains of sectors. This enabled outreach and access to relevant stakeholders that participated in sector-specific focus groups where they were (i) confronted with challenges from the demand side’s perspective, (ii) given an overview of existing EO capabilities by an EO expert with sectorial knowledge, and eventually (iii) engaged in discussions where sectorial challenges were prioritised and characteristics of possible (future) EO-enabled solutions were ideated. The richness of the input provided in these Focus Groups has not only informed the FIRE Fora but also heavily contributed to the present Roadmap and even spilled over to relevant activities such as EUSPA’s User Consultation Platform (UCP).

Thus, the proposed action is to set up similar focus groups for each market segment and to possibly benefit from the existing FIRE community where sectors addressed by the project already match some of the defined market segments. This action could either complement the UCP, which in turn could serve as one source to recruit focus group participants. Or it could be integrated in the UCP, adding a more interactive and result-oriented element.</td></tr>
<tr><td colspan="2">How

The following steps are required:

Define focus of Focus Groups: within market segments, challenges and requirements as well as suitability of space-enabled means may differ, for instance solar energy would benefit from different instruments than wind energy. Thus, some market segments would require breaking down into sub segments or applications.

Identify multipliers: rather than approaching individual actors directly, multipliers such as cluster organisations or associations representing the value chain of a market segment should be approached. Benefits for their engagement should be promoted, being e.g. visibility as key actors in that market segment, access to knowledge, options to shape research and development in directions of their interest, or providing additional benefits for</td></tr>
</table>

their members. Here one should seek to leverage public investments in existing communities (e.g. ETPs or ETIPs, KICs, EIPs, etc.).

Create a steady pool of engaged users: Through the previous steps, through the UCP or – very importantly – by introducing a prescribed obligation of end users who are partners in EU funded projects to participate in regular meetings of respective Focus Groups a steady pool of engaged users should be created. This will (a) allow continuity, (b) ensure deeper engagement (i.e. bringing these EU project users to the fore), (c) reflect latest user needs in accordance with the scope of funded R&D.

Facilitate discussions: To replicate and maintain the dynamic built by FIRE in its six sectors it is necessary that regular discussions are held between the Focus Groups. This can be facilitated by entities with a market development/user uptake mandate (i.e. EUSPA) or connected, for instance, to a revised version of the EuroGEO Action Groups. In all cases its essential that one facilitator per market segment together with selected multipliers (for access to participants and maintaining community) that speak the language of a market (sub) segment shall regularly (quarterly) gather the focus groups representing a market (sub) segment to better understand the sectorial challenges, confront them with possible solutions, and to discuss possible shortcomings and requirements towards such solutions. The participation of policy officers from relevant DGs is also highly advised as showcased through the relevant sessions of the FIRE Fora. Tools and moderators to facilitate discussion and to document results shall be in place.

- Input: challenges, possible space-enabled solutions (presentation)
- Output: requirements, ideas (discussion, documentation)
- Utilisation: transfer into follow-up discussions and activities (through suitable tool, e.g. online space) that would serve as input for subsequent focus group discussions

Maintain community of market segment actors: focus group participants need to be incentivised for both their participation in discussions as well as their longer-term commitment to accompany activities. Transfer of findings into development need to be transparent, options for participation shall be evaluated, and means for regular exchange / communication and access to materials / information should be available to make use of the gained momentum.

- Create online space for documentation of results and follow-ups with means for communication / discussion to maintain discussion beyond dedicated sessions throughout the year
- Have focus group participants present outcomes in UCP discussions
- Monitor areas of interest to define new focus groups where needed

Who

- EUSPA
- Competent DGs (for the various sectors for which Focus Groups are set as well as DG RTD in connection to EuroGEO
- Users from EU funded projects | UCP participants | FIRE Focus Group participants

Impact	
• Increased awareness on EO capabilities with segment-specific solutions • Increased number of solutions that meet very specific requirements within market segments	Impact on **end users** Low · Medium · **High** Impact on **EO service providers** Low · **Medium** · High Impact on **multipliers** Low · Medium · **High** Impact on **governance actors** Low · **Medium** · High

8.1.2 Establishment of market pull mechanisms at the "knowledge" Tier

Action number: CROSS_02	**Timeframe**
What In the last 3 years, a couple of initiatives emerged, from the European Commission or ESA, for triggering real use-cases and leveraging existing resources, in short shifting from technology push to market pull. A first example, funded by EC DG CONNECT, is Open Clouds for Research Environments (OCRE - https://www.ocre-project.eu/), a second one, funded by ESA EOP-S, is the Network of Resources (NoR - https://eo4society.esa.int/2019/06/07/network-of-resources/). Such initiatives were extremely relevant and timely when launched, but are only focusing on leveraging "Resources Tier" assets (such as CDIAS) for supporting "Exploitation Tier" stakeholders (such as EO Services Providers). Even so, their value as a first attempt at market pull is widely recognised in the European EO sector, and the lessons learnt could be leveraged for new initiatives. In that regard, and inspired by the lessons learnt from OCRE and NoR, we proposed the establishment of **market pull mechanisms for supporting market development activities at the "Knowledge Tier"**, i.e. for information providers (non-EO companies) or end-users.	Short-term 1 – 2 years **Mid-term** 2 – 5 years

How

The establishment of a market pull mechanism at the Knowledge Tier would only be successful if the services consumed (i) correspond to **real end user needs,** (ii) are to a very wide extent **"off-the-shelf"**, in other words mature, operational services that require minimal customisation. This gives rise to a three-phased approach.

Preparatory phase

The first step is to (**1) identify suitable user communities that face real cases where information derived from EO can help** and (2) **create a catalogue of the services that can meet the needs of these cases, with clear specifications and pricing**.

These use-cases should be relevant to and aligned with

Commission priorities for 2021-27, such as European Green Deal, the EU's digital strategy, etc.

Commission 5 main missions as part of Horizon Europe, such as Climate-neutral and smart cities, Soil health and food and Healthy oceans, seas, coastal and inland waters

The respective communities should be selected from and engaged through the activities of the remaining actions proposed in this roadmap. Additional inputs into this preparation phase can be collected from existing initiatives across Europe.

Having collected relevant use-cases and solicited the targeted user communities (in conjunction with the Focus Groups discussed previously), dedicated calls for solutions could be launched, at the Knowledge Tier, looking for European Startups, SMEs, Mid-Caps, Large Companies and Research Organizations that would like to develop, test and validate the technical solutions that address the specific challenges, including and leveraging existing

EO services. This could be supported by dedicated Horizon Europe calls (which had in the past supported relevant projects) or new instruments by EUSPA/ESA.

The resulting catalogue of the services can be created in collaboration with EARSC, leveraging its involvement in OCRE and the work done under eoMALL. Special attention should be placed on creating standardised metadata for each service that enters the catalogue, that reflect the way users understand the needed services and not the way EO service providers are currently advertising them.

Launch and implementation phase

The awarded projects should ideally foresee the gradual detachment from public funding. Thus, while the first years can entail full or partial funding by the EU, from year three onwards the resulting services should be self-sustained. Voucher schemes may also be relevant in this regard.

Overall, this will really pull the market and contribute to the usage of information derived from EO by new users. A piloting of this approach could be foreseen in one selected sector/user community and then expand it in additional ones.

Who

- **EUSPA**: Promoting its role as a market development agency and market pull activities that target new end users,
- **A Third-Party Legal Entity** for implementing such market pull mechanisms in a sustainable and long-term perspective, with a very clear governance and business model
- A number of **User Communities** who will benefit from EU-sponsored consumption of EO services meeting their expressed needs, and commit to then continue purchasing these services once they have seen their value
- A number of **EO Service Providers** offering their services in response to identified needs

Impact

- Increased awareness on EO capabilities with segment-specific solutions
- Increased number of solutions that meet very specific requirements within market segments

Impact on	Low	Medium	High
Impact on **end users**	Low	Medium	**High**
Impact on **EO service providers**	Low	Medium	**High**
Impact on **multipliers**	Low	Medium	**High**
Impact on **governance actors**	Low	**Medium**	High

8.1.3 EO data and services for non-traditional user communities

Action number: CROSS_03	**Timeframe**
What The engagement of users in FIRE has shown that on one hand there is still plenty of scope for market development in traditional EO applications and, on the other, new opportunities arise together with evolving user needs. Whilst many of the actions proposed under the specific sectors address identified needs, there will always be some areas or user needs that are not fully covered. To address such gaps, the need for the roll-out of an instrument that is continuously available yet more agile, in that it responds to evolving needs as they are dictated by the market, has been identified. Such an "EO-START" instrument should allow the pairing of end-users with one or more EO service providers for a short project aimed at investigating feasibility or looking at how an operational service might work. The key differentiator of such an instrument with respect to a traditional marketplace is that it would not just provide a forum for users and providers to meet (effectively building on and extending what FIRE has set up) but would allow the consumption of both off-the-shelf services (in synergy with the previous action) and customisable (and, ideally, co-designed) services. The EO-CLINIC[44] run by ESA gives an indication of how such a service might operate.	Short-term 1 – 2 years **Mid-term** 2 – 5 years

How

Instrument Setup: As with the previous action, here too the mobilisation of the necessary funds is required. This could involve a dedicated Horizon Europe call (IA) or a dedicated budget line under EUSPA. The first step would be then to issue a call for EO service providers who will be onboarded to the instrument. Each provider will specify their capabilities and prices. It may also be necessary to have a separate call for independent experts who can be involved in the management of the service. It is also recommended to approach several key users ahead of the service launch, asking them to submit some initial requests. This will give an early set of case studies that can be used to further publicise the service. Synergy with the EuroGEO Action Groups (in a revised EuroGEO concept) would also be beneficial as it would help establish a pipeline from R&D to operationalisation.

Instrument Operations: Once active, the instrument operations would proceed as follows:

1) A request for a service is received from a user.
2) The service management assesses the request. If it is considered valid then a subset of service providers who might be interested are identified, and the request passed to them.
3) The service providers respond with a proposal. The service management assess the proposals and make a recommendation to the user to proceed with one option.

[44] https://eo4society.esa.int/eo_clinic/

4) The user and provider work together, over a period no longer than 3 months, to refine the solution.

5) At the end of this period a review is held to assess the success of the project against the original objectives. Based on this a continuation may be agreed outside the framework of the service.

6) The service provider shall be paid for by the user, except for the management costs which are incurred by the funding authority (Horizon Europe or EUSPA).

Who

- Competent EC actors being either DG RTD (if this is embraced as a Horizon Europe initiative linked to EuroGEO) or EUSPA (as part of market development activities)
- To support the service management, independent experts may be recruited to assess proposals. This could include the involvement of entities such as ESA or JRC.
- A broad range of Service Providers should be approached to be onboarded to the service. These should cover expertise in several domains and in multiple techniques. Coordination with EARSC would be advised.
- A small number of target users should be approached to submit an initial set of requests, leading to successful case studies that can be used to promote the service to others.

Impact

- Increased adoption of EO based services by non-traditional users or in non-traditional applications
- Strengthened go-to-market capability for the EU EO service providers

Impact on **end users**		
Low	Medium	**High**

Impact on **EO service providers**		
Low	Medium	**High**

Impact on **multipliers**		
Low	Medium	**High**

Impact on **governance actors**		
Low	**Medium**	High

8.1.4 Centralised repository of user-oriented use cases

Action number: CROSS_04

Timeframe

Short-term 1 – 2 years | Mid-term 2 – 5 years

What

One of the obstacles which often limits or slows down the uptake of EO-based solutions, notably in the Member States where the EO industry is not well-developed, is the lack of informed customers. The awareness actions performed during these last years by the various actors involved in the Copernicus programme have strongly contributed to increase general awareness and make the programme better known, including in the above-mentioned Member States, but they were not always well-fitted to convince end-users that Copernicus (and more generally EO) could help them in their daily activities. This realisation has been strongly highlighted in virtually all sectors covered by FIRE.

A main difficulty for potential users having heard that "Copernicus could help" is to find concrete examples of what Copernicus can do for them in their specific business, ideally with testimonies from other users already benefitting from Copernicus-based solutions.

Considering this, the proposed action contemplates the **setting-up of a centralised repository of user-oriented use cases illustrating concrete uses of Copernicus in all the domains / market segments where the programme can bring added-value**.

How

The action should start with an **inventory of existing examples of Copernicus use cases**. A good starting point for this identification are the use cases developed by the Entrusted Entities[45], the work done by JRC with the Knowledge Centre[46] (which however focusses on EU policy making) and the work done by ESA[47]. The network of Copernicus Relays and Academies could also be mobilised to identify use cases in their respective country / region as could the participants of the EuroGEO Action Groups.

Then, a **common way of presenting the uses cases should be defined** (the various sources mentioned above have been developed in a fragmented way and all have their own way of presenting use cases, structuring information, etc.). For instance, some of the CAMS uses cases include users' quotes while other do not; CMEMS use cases include a "Benefits for users" section but do not indicate who the real users are; EARSC use cases clearly identify users but do not include users' quotes. The common structure to be defined should:

- Make sure that the domain/business area targeted by the use case is clearly defined;
- Make sure that the type(s) of users potentially interested by the use case is clearly defined;
- Include the testimony from a user;
- Be solution-oriented rather than technology-oriented since in most cases end-users are interested what the solution brings to them, not in how it works.

Once defined the structure and layout of the use cases, the next step would consist in **producing the use cases**, i.e. in "converting" into the new format the use cases gathered through the first phase of the action. Note that

---

[45] See for instance https://marine.copernicus.eu/services/use-cases and https://atmosphere.copernicus.eu/use-cases
[46] https://knowledge4policy.ec.europa.eu/earthobservation_en
[47] See for instance https://earsc.org/sebs/all-cases/ and https://esamultimedia.esa.int/docs/EarthObservation/copernicus4regions_2018.pdf

this conversion phase is not something that can be automated. It implies a true editorial work since the various information sources differ both in structure and content of the use cases they propose. It is also the moment where the **"users-talk-to-users" principle should come into play**. Indeed, it is crucial that the use cases are user-oriented and show what the concrete benefits are, through user testimonies. Considering that many of the existing use cases do not indicate who their users are and do not include testimonies, further investigations and interviews would probably be required to gather the necessary information (types of users, user testimonies) which will serve as basis for the re-drafting of the use cases. A **validation phase** with the originator of the use case (e.g. Entrusted Entities, NEREUS, EARSC) might then be needed.

The last step of the action would consist in **making the use case descriptions available online**, ideally through the Copernicus.eu website (and to promote them through EUSPA, ESA, JRC, etc.). Particular attention should be paid to the user-friendliness of the access, the best option being to have the use case descriptions accessible through a searchable database (the interface of the access proposed by the Copernicus Marine Environment Monitoring Service CMEMS being a good example). A "**Submit your use case**" function should also be foreseen so that users and/or providers have the possibility to submit new use cases for publication.

Who

- EUSPA: Identification of operational use cases and creation/update of a dedicated repository on the EUSPA website.
- Copernicus Relays & Academy: Supporting the identification of operational use cases in their country.
- Copernicus Entrusted Entities / NEREUS / EARSC: Supporting the identification of operational use cases

Impact

- Increased awareness on concrete benefits from EO based services for users

Impact on	Low	Medium	High
Impact on **end users**			**High**
Impact on **EO service providers**	**Low**		
Impact on **multipliers**			**High**
Impact on **governance actors**		**Medium**	

9 Conclusions and future work

The FIRE Roadmap has sought to distil the many exchanges among actors across the complete value chain taking place in the FIRE Focus Groups and the FIRE Fora and, after combining this with rigorous analytical work, **illuminate a path for the development of the EO sector in Europe**. For each of the six sectors, Europe can gaze upon this path with confidence and optimism but also with a sense of responsibility; we have world-class capabilities reflected on the European infrastructure itself (especially Copernicus) but also embedded in the work of researchers and innovative companies. These capabilities give rise to services across a wide range of applications that generate significant benefits for users. Yet, the uptake of such services can be significantly increased through coordinated and ambitious plans. This is precisely what the Roadmap has hopefully shed light on. It has identified common themes across the sectors such as

- Further **incorporation of EO in relevant policy and regulation**
- Coordinated support for **market development** that is primarily **driven by market pull mechanisms** and reflects the evolving needs of users
- Systematic effort to increase the **uptake of EO both in established applications but also new areas** that may currently be a small niche but have the dynamic to grow in the near future
- Progress required in aspects such as **data governance, interoperability and standardisation** extending from the technical levels down to the level of user interfaces
- Comprehensive **capacity development** so that the various users are empowered to make the most of EO-based solutions
- **R&D** that focusses on the exploitation of cutting-edge techniques (AI/ML), fusion of different types of data and new sensing capabilities

The work presented herein is by no means the final word on the subject. On the contrary, our hope is that it will stimulate the conversation among policy makers, innovation support actors, EO solution developers and users, so that the aforementioned benefits are maximised. We hope that the proposed actions will provide a seed for activities taking concrete shape in the years to come; such activities will certainly be adaptations of what is proposed here or altogether different but hopefully inspired by some of the ideas reflected in this document. In that regard, developments driven by actors involved in the governance of Copernicus (DG DEFIS, ESA, EUSPA, Entrusted Entities) but also DG RTD as the key actors for R&D in the EU and the manager of EuroGEO, can be, hopefully, informed by what has been laid out here.

The FIRE consortium has worked hard together with the stakeholder communities in the six sectors to produce this document and will actively seek to animate the conversation on the findings and recommendations discussed here. We are committed to do so both within the timeframe of the project and beyond.

Our partners