

A circular graphic composed of several colored segments: orange, blue, red, and teal. The segments are arranged in a ring around the central text.

ESA COMMERCIALISATION GATEWAY

POWERING
SPACE
INNOVATION

Market perspective
2024 Edition

About the ESA Commercialisation Gateway

Since 2019, the European Space Agency (ESA) Commercialisation Gateway has been a key entry point for new actors - such as startups, new talents, and non-space industries - interested in engaging with ESA. Our mission is to foster the commercialisation of space, notably by showcasing space-related market trends and successful use cases.

Through these efforts, the Commercialisation Gateway gains sector-specific expertise, supports transformative actions within ESA, and adapts to new demands in space-related business.

Purpose of our brief market intelligence reports

From 2022 to 2024, the ESA Commercialisation Gateway produced a series of brief market intelligence reports, offering a strategic glimpse into some of the most promising upstream and downstream markets. These reports comprehensively analyse general trends, demand and supply overviews, space-based solutions, competitive landscapes, business models, barriers to entry, and support mechanisms.

This collection provides strategic insights, guiding stakeholders through the dynamic space commercialisation landscape. It aids decision-makers in staying attuned to market trends and crafting innovative strategies, and shifts. Ultimately, these reports enhance ESA's positioning, and elevate awareness among external actors regarding ESA financial and technical support opportunities.

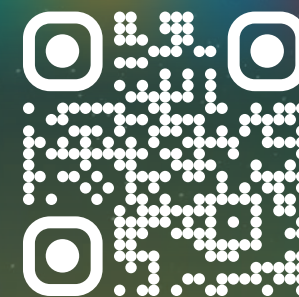
The Market Perspective, 2024 Edition

This Market Perspective booklet compiles the valuable insights from the brief market intelligence reports published from 2022 to 2024, focusing on downstream reports that explore the added value of space technologies in terrestrial applications. Additionally, this edition includes one transversal report on the value of AI in both upstream and downstream markets.

This booklet serves as a strategic resource, providing stakeholders with a comprehensive understanding of the evolving market landscape and the transformative potential of space technologies.

We invite you to delve into these insights and join us in leveraging space innovations for a better, more sustainable world.

Commercialisation.esa.int



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Space for renewable energy

**Space commercialisation
for renewable energy**



Space commercialisation for renewable energy

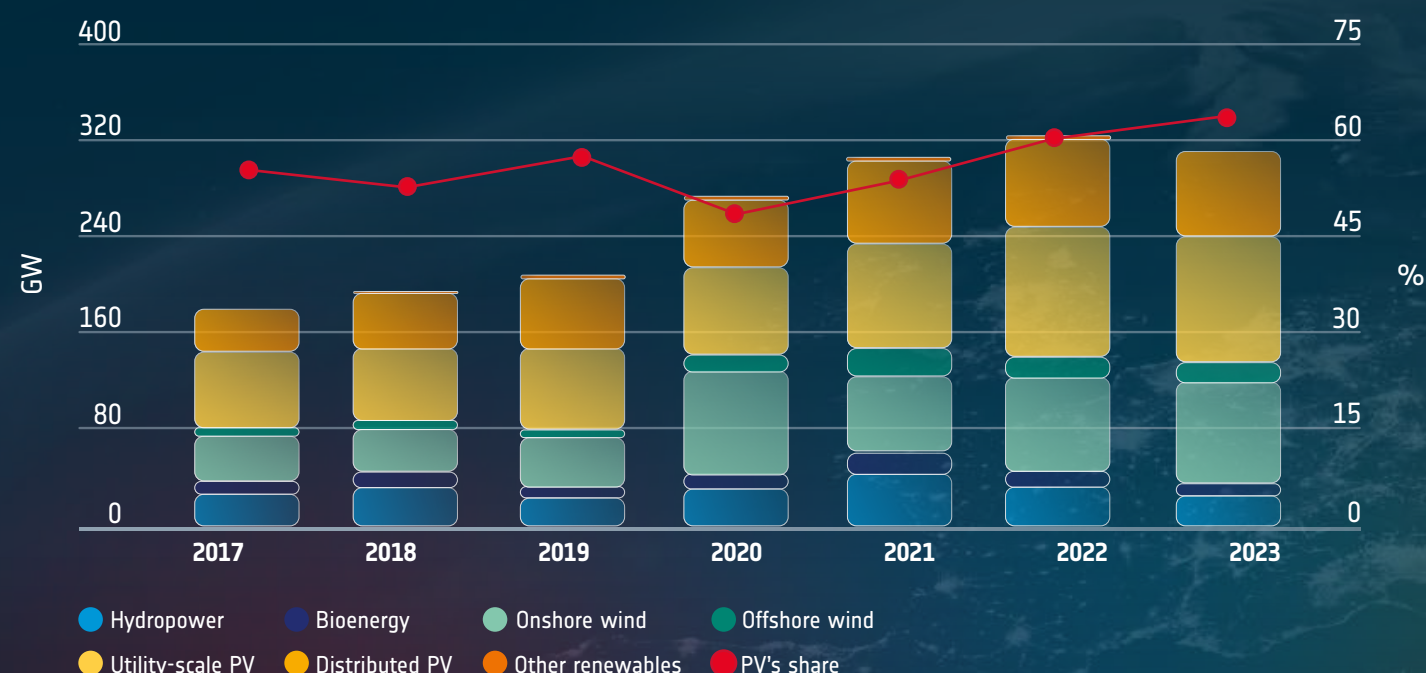
The rise of renewable energy

Against a backdrop of surging energy requirements, a growing awareness of the environmental impact of CO2 emissions, and an uptrend in the prices of raw materials, renewables are becoming the main source of electricity generation. Technological innovation and public policy have boosted the cost competitiveness of renewable energy sources, leading even greener impetus to their success story. Increasing environmental dependencies and new communication needs for hard-to-reach power generation facilities are opening up unique commercial opportunities for the space sector. This document gives an overview of the related use cases and opportunities, and can help both actors from the space and energy sector to identify synergies between the two markets.

Renewable energy sources play a key role in Europe's aim to be climate neutral by 2050. In the European Union,

renewables accounted for nearly 40% of total electricity generated in 2022, with wind and solar power representing 22%. Compared to 2021, solar grew by 38TWh while wind rose 33TWh in Europe¹. These developments place Europe and its industry in a position of leadership in the clean energy transition.

Beyond European borders, demand for clean energy is also increasing. Ensuring access to energy is part of Sustainable Development Goal² 7, as access to electricity is still out of reach for some 770 million people, mostly in Africa and Asia³. Innovative renewables and local off-the-grid systems (including hydro, solar photovoltaics or hybrid mini-grids) are on the rise worldwide, supporting access to green energy.



Net renewable worldwide capacity 2017-2023
(source: International Energy Agency)

1. EUROPE: RENEWABLES IN 2022 IN FIVE CHARTS – AND 2023...
2. THE 17 GOALS | SUSTAINABLE DEVELOPMENT...
3. ACCESS TO ELECTRICITY – SDG7: DATA AND PROJECTIONS



SOLAR

The most competitive renewable energy source. Innovative types are integrated photovoltaics (PV), agrophotovoltaics, floating PV, and road integrated PV, PV plus storage, and more⁴. Represents 62.3% of all renewable capacity worldwide in 2023¹.



WIND

Abundant and predictable. Innovative types include deep water, floating, hybrid and urban wind. Offshore wind is on the rise in Europe and is predicted to produce a total of between 240GW and 450GW by 2050⁵. Currently, net renewable capacity additions represent 81GW for onshore wind and 10GW for offshore worldwide⁴.



HYDRO

Flexible, predictable and allows for energy storage. Growing trend for local and small-scale micro-hydro and pico-hydro systems. Now, Europe has nearly one quarter of worldwide hydropower capacity⁶, making it a key pillar of the clean energy mix.



MARINE

Europe is leading the development and it is anticipated to produce 1GW of marine energy by 2030 and 40GW by 2050. Wave energy converters have 1.5MW currently operational in Europe. Tidal energy is expected to reach a deployment of 4.6GW in Europe by 2027. Thermal conversion, salinity gradient and current technologies have low Technology Readiness Levels (TRLs).



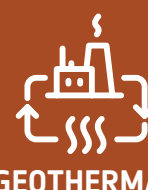
BIOENERGY

The source is usually fast-growing, energy- and biomass-rich crops. Usage includes transport and heating (mainly in Europe and America). Production of global biofuels is growing, mainly in ethanol and biodiesel.



HYDROGEN

Used as a feedstock, fuel, energy carrier and for storage. The European Commission predicts the share of hydrogen in Europe's energy mix to rise from less than 2% currently to 12-14% by 2050.



GEOTHERMAL

Reliable, low cost, and competitive with fossil fuels. Earth's geothermal reservoirs are near tectonic plates/volcanos. Mostly used for district heating, not energy production.

4. NET RENEWABLE CAPACITY ADDITIONS BY TECHNOLOGY...
5. WINDEUROPE-OUR-ENERGY-OUR-FUTURE.PDF...
6. JRC HYDROPOWER STORAGE IN THE EUROPEAN UNION – 2022...

Renewable energy in Europe

The renewable energy ecosystem is complex as it includes asset planning, financing, operations, transmission and distribution as well as consumption by end users. Governments and regions are heavily involved through tariffs, regulations and subsidies. Yet this slow-moving sector is experiencing disruption from start-ups.

In Europe, some of the 3 largest developers by assets include Enel Green Power (Italy), EDP Renovaveis (Spain) and Volterra (France). Mostly, they focus on solar farms and wind parks. Other large players are BayWa (Germany), Scatec (Norway), and Iberia Solar (Spain)⁷.



Germany, Spain, and Poland lead the sector⁸. Major companies are Iberdrola (Spain), Enerparc and Encavis (both from Germany), Octopus (through partnership with Lightsource BP) and the Foresight Group (both from the UK).



The leading European countries in terms of capacity are Germany, Poland, Denmark, Spain, and the UK⁹. Companies such as Siemens Gamesa (Spain), Vestas Wind Systems (Denmark), and Nordex (Germany) lead the wind sector.



Norway, Sweden, and France generate the most hydropower in Europe¹⁰. Europe is home to several leading commercial players. The major technology providers are Andritz Hydro (Austria), Voith (Germany) and GE Renewable Energy which acquired Alstom's power grid businesses (France).



Europe is leading the development of marine energy. The UK, France and Portugal especially are driving the sector. Key firms include Nova Innovation (UK), Wave Energy Scotland and Seabased (Ireland).



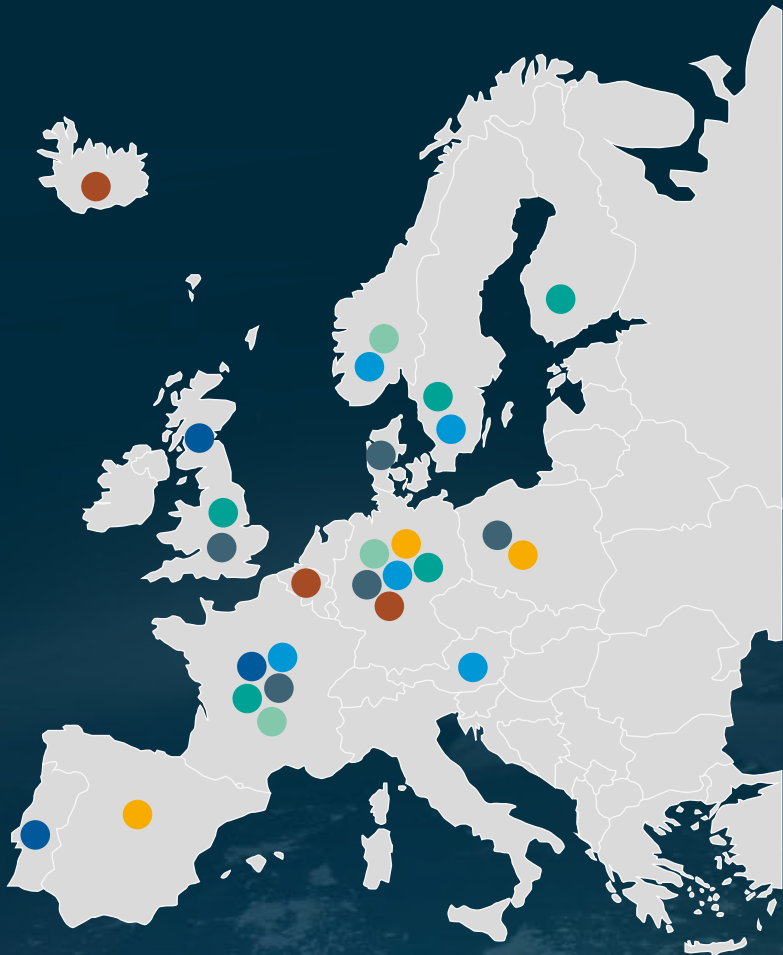
Germany, France and Sweden are leaders in biomass production in the EU. The main companies in the production of wood-based energy sources in Europe include Drax Group (UK) and Stora Enso (Finland), and Poet is a major player for biofuels in the US.



Germany is a leading player and has consequently established a National Hydrogen Strategy. The main European companies are Air Liquide (France), Nel Hydrogen (Norway) and Linde (Germany).



Iceland is a leader in the sector, covering 90% of its household heating needs with geothermal energy¹¹. The main European companies include Enel (Italian), Tractebel Geothermal (Belgium), Geothermal Group (Germany), and Iceland Geothermal (Iceland).



- 7. LIST OF THE 450 LARGEST RENEWABLE ENERGY DEVELOPERS...
- 8. EU MARKET OUTLOOK FOR SOLAR POWER 2022-2026...
- 9. WIND POWER NUMBERS | WINDEUROPE...
- 10. EUROPE (HYDROPOWER.ORG)...
- 11. GEOTHERMAL ENERGY | ICELAND RENEWABLE ENERGY CLUSTER...

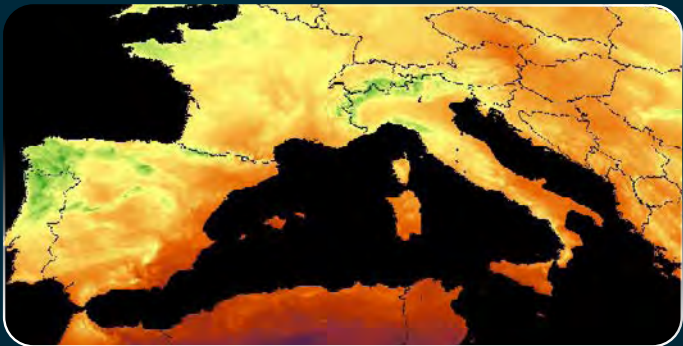
Energy sector needs and space related use cases

The energy sector is undergoing a major transformation, providing space-based companies with new commercial opportunities in fields ranging from Earth observation to telecommunication and technology transfers. The ever more complex and decentralised systems are increasingly dependent on their natural environment and are often located in remote areas. They also require forecasting, connectivity and a multidirectional flow of energy and information. The

general role of data is increasing and energy-as-a-service as well as energy-data-as-a-service business models are emerging. Active "prosumers" (producers and consumers), increasing electrification and the need for planning and storage are further revolutionising the energy sector, with even financially conscious investors now attentive to how clean assets are. The requirements most relevant to space-based services and applications are the following:

1. DUE DILIGENCE AND LOCATION SCOUTING

Selecting locations with the highest potential for energy generation is a key success factor for renewable energies, and especially relevant for solar, wind and marine assets. The sector needs renewable energy resource mapping through detailed and long-term statistics on solar irradiance, wind speed and direction, run-off due to snow cover, geothermal anomalies, biomass crops, etc. This is true of areas that are not easily accessible, or of larger areas that need to be scanned and where in situ approaches are not suitable, as, for instance, is the case with wave and offshore wind power.



Solar irradiance map of Europe

2. SYSTEM PLANNING

There is a need for selecting production and transmission infrastructure sites based on a combination of resource information with data on the local or regional environment, existing land and infrastructure characteristics, natural hazards, etc. In solar energy, for instance, this process would include the assessment of the PV (photovoltaic) potential that can be harvested from rooftops (including in urban areas), water bodies, etc. In transmission infrastructure, this involves the deployment of least-cost solutions through grid expansion/intensification/densification and mini-grids. Energy demand can be characterised by mapping settlements, important public infrastructure, potential irrigation areas and other indicators of economic activity where electricity consumption is high.

Given the increasing number of prosumers, creating inventories of existing energy infrastructure is important, especially in regions where available data is limited. These inventories are created by mapping features such as high-voltage and, more importantly, medium- and low-voltage power infrastructure and networks, etc. Space can also help in monitoring progress in electrification.



Nocturnal picture of Europe, exhibiting its light consumption

3. BANKABILITY AND EFFICIENCY

One of the main challenges that renewables face is reaching economic margins that allow them to compete with other energy sources. Specially, in a time of evolving feed-in tariffs as well as higher exposure to market prices. Currently, solar power has developed new financing options, such as solar leasing and power purchase agreements, resulting in wider adoption as it expands into developing countries. Wind is also becoming an attractive sector as the levelised cost of electricity of offshore wind decreases. Yet pressure is mounting to understand long- and short-term output generation, and to reduce and optimise maintenance cycles and approaches. For more efficient management of energy production operations using biomass, for instance, a wide range of information is needed, including on available and/or forecast biomass crops, available solid fuel in the form of waste accumulated at managed waste sites and extreme weather events that would cause significant variations in the expected energy demand. In addition, offshore wind and other hard-to-reach-installations need predictive and automated maintenance control technologies (such as for cleaning solar panels from dust and repairing turbines) along with long-range communication tools to improve efficiency and reduce costs. Drones may support inspection and cleaning.



Offshore Wind Farm

4. ENVIRONMENTAL AND SOCIAL IMPACT

To be recognised as “green”, environmental preservation during the construction and operation of the facility where a particular form of energy is produced is key. To minimise the impact of wind power on sky wildlife (e.g. birds and bats) and the changes to river ecosystems caused by hydropower, Europe has reduced large-scale new projects. Marine energy must prove that any negative influence on fish routes, marine habitats and coastal ecosystems is limited, and also reduce harmful liquid spills. Bioenergy requires the capability to monitor the impact of biomass/biofuel production on land use, in particular with respect to deforestation.



Data from Swarm overpasses with GPS tracking points of migratory animals

5. PROTECTION FROM CLIMATE RELATED HAZARDS AND RISKS

Renewables are highly susceptible to weather changes at remote natural sites. The vulnerability of energy infrastructure needs to be assessed by estimating climate and disaster risks in the zone (floods, landslides, erosion, etc.), and by monitoring external threats such as natural (vegetation) encroachment on transmission lines. Awareness of climate risks means that protection can be applied to lower the risk of damage to installations and avoid lower energy production. Some examples include extreme temperatures for PV cells, which operate better when cold, or the melting of glaciers due to climate change, which affects hydropower capacity.



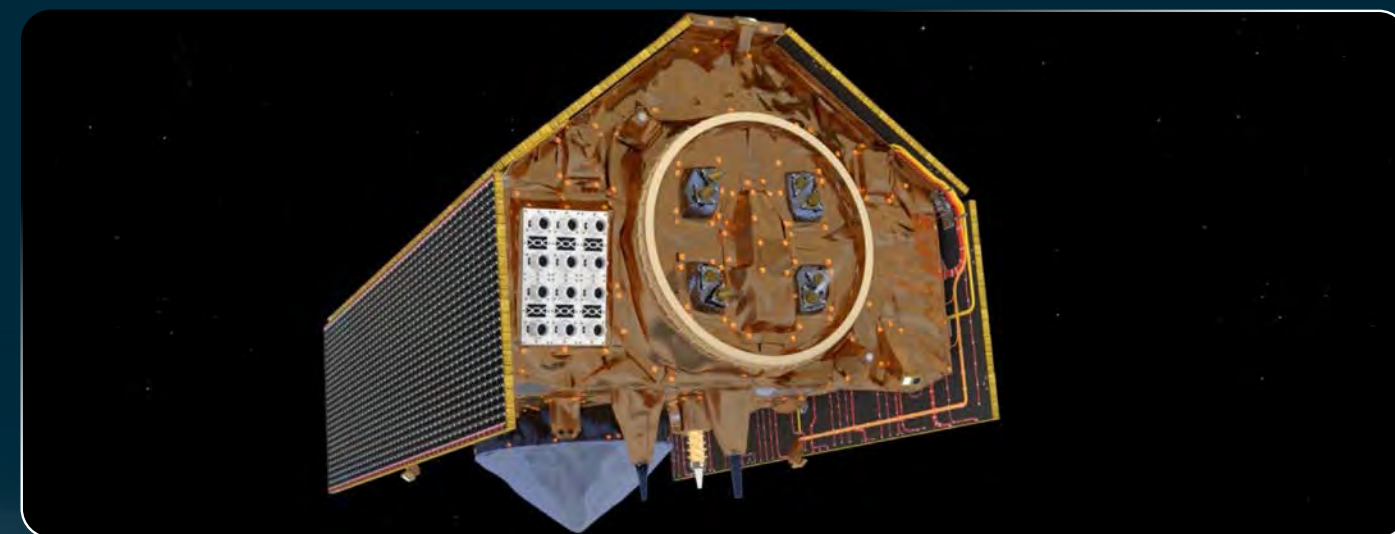
Flooding caused by heavy rains

Public and commercial space added value

The space and energy sectors intersected for the first time over 60 years ago with the technological development of solar cells. As renewable energy assets rise worldwide, space is becoming indispensable.

Renewable energies will drive the energy agenda further thanks to favourable conditions from a technological, policy and financial perspective. It can be assumed that this development will have a highly positive impact on the use of weather and other satellite-based data due to increasing dependency on environmental conditions, digitalisation (energy-as-a-service) and the need for forecasting (owing to changes in feed-in-tariffs).

Solar and wind energy especially are set to be deployed on an even larger scale over the future years and decade. The increase in renewables heightens the energy sector's volatility proportionally, and therefore the need for climate information. Copernicus is an Earth observation programme headed by the European Commission in partnership with ESA, that provides a wealth of data, both recent and historical, and services. Small subsets of all the data available is featured in the following examples per service:



Copernicus Sentinel-6 solar panel deployment

Copernicus Atmosphere Monitoring Service (CAMS)

Monitors air quality for the operational efficiency of PV and wind turbines. Supports localised solar energy potential estimates, based on retrievals and modelling of solar irradiance parameters. Its meteorological services (wind, cloud cover, etc.) can assess the potential risks of low variable renewable energy supply.

Copernicus Climate Change Service (C3S)

Predicts weather patterns to manage risks efficiently for planning and forecasting. Through optical and radar sensors, shows snow cover, runoff estimates, land surface temperatures, soil moisture, and other EO-derived parameters relevant for river basin management, hydropower potential estimation and operations. The data is freely accessible in the Climate Data Store.

Copernicus Marine Environment Monitoring Service (CMEMS)

Uses scatterometer and synthetic aperture radar (SAR) data to provide information on marine surface wind speed and direction, allowing offshore wind energy potential estimates to be calculated.

Copernicus Land Monitoring Service (CLMS)

Provides data on land cover, land use, and vegetation, useful for location scouting and environmental impact. Uses various satellite data sources, including optical and radar sensors, to provide information on biomass, such as crop acreages, yield estimates, irrigated crop acreages and irrigation potential mapping, which is based on a combination of climate, soil, and crop type data.

Based on public space infrastructure, new commercial models have been emerging. For example, LAUTEC'S ESOX tool uses wind and wave information from SAR sensors to support wind farms, and Vortex maps wind resources and provides location assessment. Larger private renewable companies using space applications include 3TIER (Finland, forecasting), and Clir Renewables (Canada, monitoring and optimising wind power).

The European Space Agency contributes to commercial approaches to supporting the growing renewable energy sector. ESA operates Business Incubation Centres (BIC)¹² across its Member States and these have helped a variety of energy-related companies by providing access to funding, networks and business support. BIC-supported firms include Polar and Sobolt in the field of solar energy, Farwind Energy and Eolion Energia for wind power and Alphaedge GmbH in the hydro energy sector. TIA BASS¹³ supports demonstration projects in the field of energy. FUTURE EO¹⁴, for example, supports offshore and marine renewables through the Atlantic Regional Initiative¹⁵. InCubed¹⁶ supports companies using Earth observation data, and Global Development Assistance (GDA)¹⁷ works with international financial institutions such as the World Bank to improve access to energy in developing countries.

With a view to increasing the role of space in directly mitigating the climate crisis, ESA has kicked-off a

preparatory R&D initiative, known as SOLARIS¹⁸, to mature the feasibility of space-based solar power as a potential game-changing source of clean, affordable, continuous, abundant and secure energy. Sunlight is on average more than ten times as intense at the top of the atmosphere as it is down at the surface of the Earth. At a sufficiently high orbit sunlight would be available on a continuous basis. Solar power could therefore be collected 24/7 by huge solar farms in space and beamed to receiving stations across the planet, wherever it is needed. SOLARIS will prepare a decision by 2025 on whether Europe should embark on a full development programme towards delivering commercially-viable, clean energy from space in the 2030's.

Technology transfers are taking place through spin-ins and spin-offs. Moreover, the Micro-Ecological Life Support System Alternative (MELISSA)¹⁹ is an initiative aiming to develop the technology for a future regenerative life support system for long-term human space missions. Additionally, ESA's Space for a Green Future Accelerator responds to the global climate and environmental crisis, in support of a sustainable green transition.

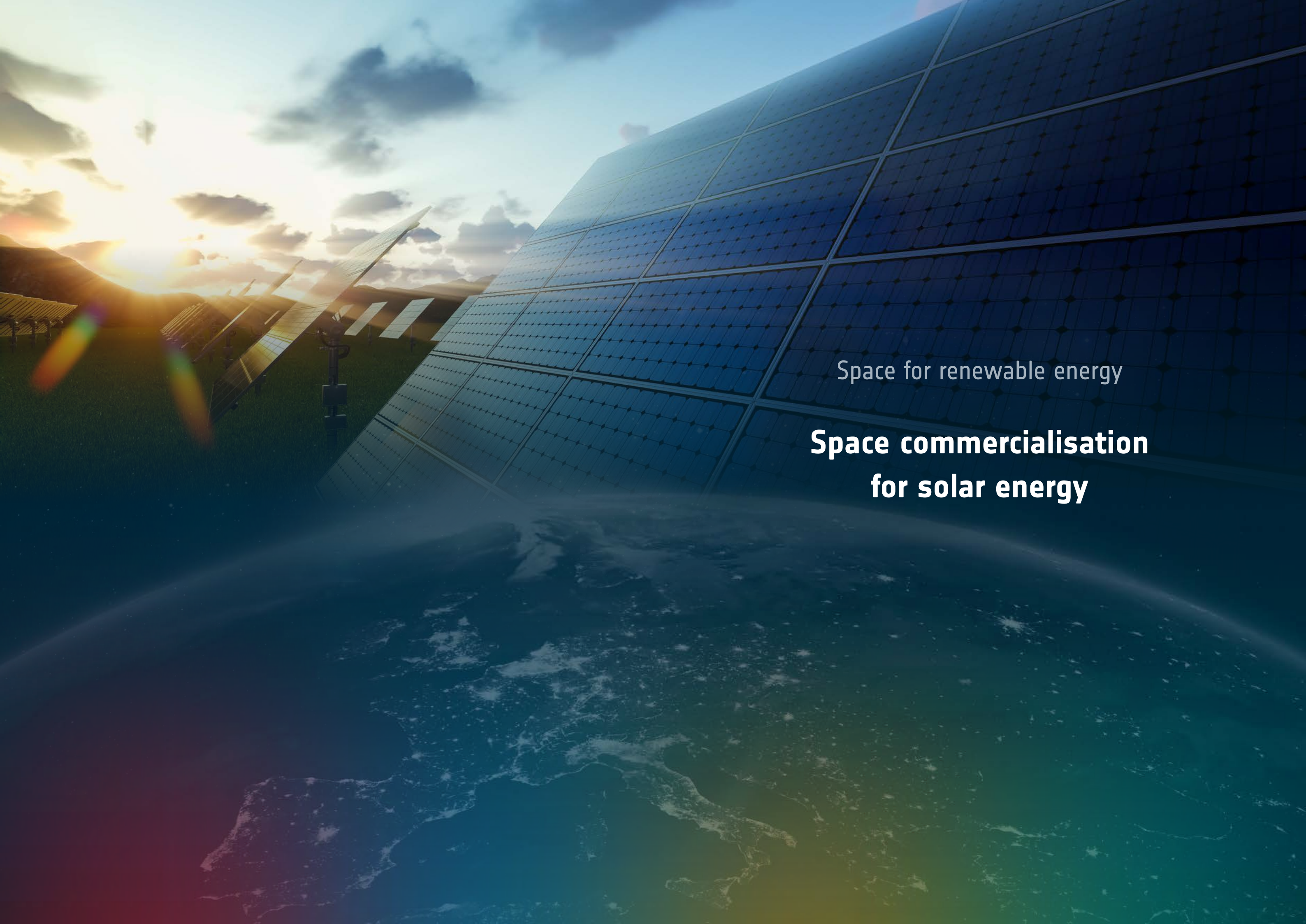
In conclusion, renewables are a booming industry with emerging needs and high institutional economic support, resulting in promising commercial opportunities for space-based companies over the years to come.



Space-Based Solar Power for Earth's energy needs

- 12. BUSINESS INCUBATION CENTERS (BIC)...
- 13. TIA BASS...
- 14. FUTURE EO...
- 15. ATLANTIC REGIONAL INITIATIVE...
- 16. INCUBED...
- 17. GLOBAL DEVELOPMENT ASSISTANCE (GDA)...
- 18. SOLARIS...
- 19. MICRO-ECOLOGICAL LIFE SUPPORT SYSTEM ALTERNATIVE...



A large, dark blue solar panel array, composed of many smaller rectangular cells, is shown in a perspective view, extending from the bottom right towards the top left. It is positioned in space, with the curved horizon of the Earth visible below. The Earth's surface is a mix of blue oceans and white clouds. In the upper left, the sun is setting or rising, creating a bright, hazy glow and casting long, colorful lens flares across the scene. The sky is filled with soft, white and grey clouds. The overall color palette is dominated by the blues of the solar panels and Earth, the oranges and yellows of the sunset, and the greys of the clouds.

Space for renewable energy

**Space commercialisation
for solar energy**



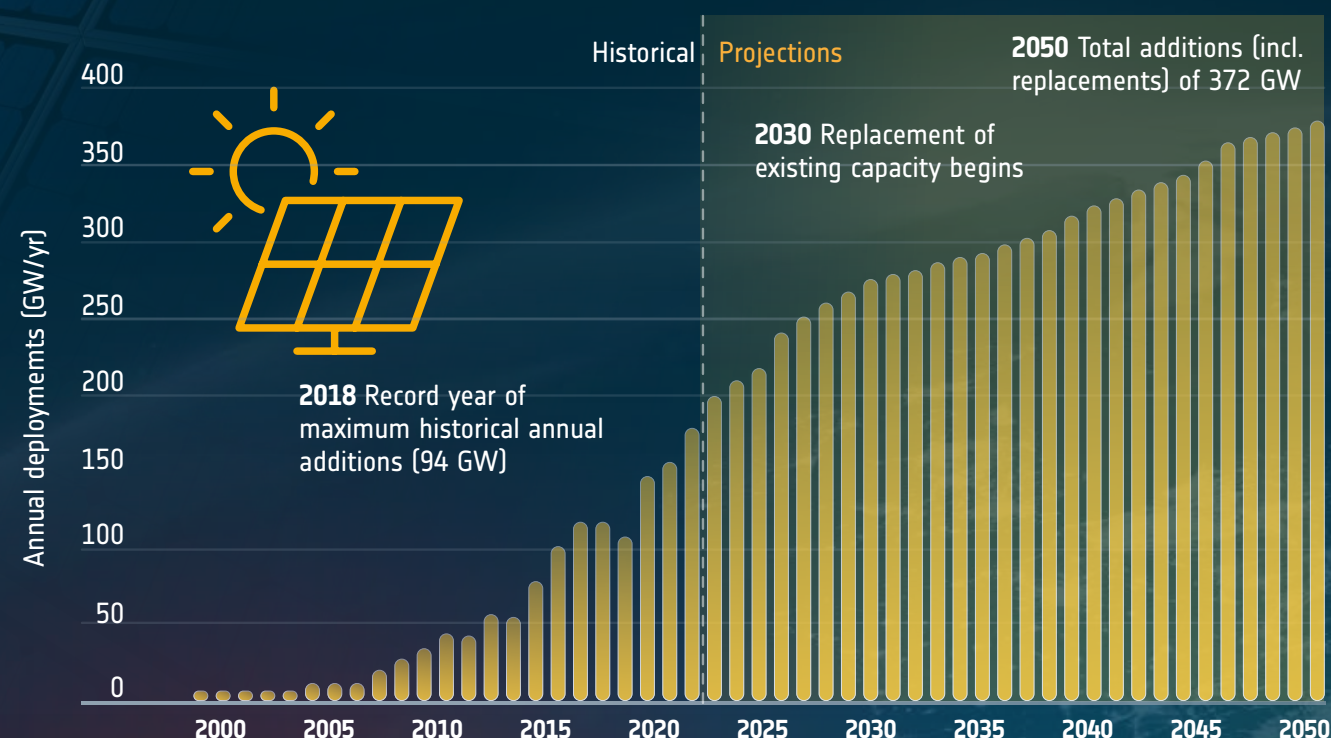
Space commercialisation for solar energy

The rise of the solar energy sector

Renewables are on the rise worldwide, a phenomenon in which solar energy is playing a particularly important part. In 2022, global installations amounted to 268 GW of new solar capacity, with this figure expected to rise to 315 GW in 2023¹. In the next decade, installations of solar photovoltaics (PV) are expected to increase sixfold reaching a global capacity of 2,840 GW by 2030. The International Renewable Energy Agency (IRENA) expects solar photovoltaics and wind power to lead the electricity market transformation by 2050, with solar power becoming the second largest source and covering 25% of global electricity needs. Worldwide PV capacity is expected to consist of 40% distributed (rooftop) and

60% utility-scale power. In particular, distributed solar PV installations are expected to grow rapidly as a result of consumer engagement and supportive policies².

With electricity demand projected to continue to grow, and with access to energy among the Sustainability Development Goals (SDG 7), solar offers unique added value in providing access to clean energy. Off-grid solar solutions, for example, grew by 18% in 2022 in developing Asia and sub-Saharan Africa³. In total, since 2010, more than 180 million off-grid systems have been sold, including 150 million pico solar products and 30 million solar home systems.



Annual global solar PV additions are expected to reach to 270 GW in 2030 and 372 GW in 2050 under the REmap scenario, compared with 94 GW in 2018 [source: Own illustration based on IRENA and IEA data, 2023]

1. GLOBAL SOLAR CAPACITY ADDITIONS HIT 268 GW IN 2022...
2. FUTURE OF SOLAR PHOTOVOLTAIC – A GLOBAL ENERGY...
3. CUMULATIVE GROWTH OF OFF-GRID SOLAR PV APPLICATIONS...

European solar energy landscape and stakeholders

In Europe, almost 40% of total electricity was generated by renewables in 2022. Solar was the most competitive source, with a total capacity of 209 GW (50% year-on-year growth rate), and could reach up to 1 TW by 2030 (672 GW in a business-as-usual scenario)⁴. To make this possible, and complementing national actions, the European Commission presented further steps to speed up solar deployment in the REPowerEU package, which provides new guidance on enabling a Solar Rooftops Initiative, a Solar Photovoltaic Industry Alliance and a Solar Skills Partnership.

Today, the top five EU solar power markets are responsible for two thirds of the installed capacity in the region. Some of the largest European solar asset owners are Enerparc, Encavis, Octopus (through partnership with Lightsource BP), the Foresight Group, Sonnedix and Encavis.

In many countries, solar PV is already cheaper than retail electricity, but further application will depend, particularly for utility-scale projects, on national regulations on aspects such as auctions, tenders, feed-in tariffs, feed-in premiums, sun taxes, net-metering options (e.g. the Netherlands, Poland) and building, among others. At the consumer level, demand for home installations in the form of PV plus storage is increasing for energy price security and autonomy reasons. The number of new “prosumers”⁵ in Germany, for example, was already estimated at 100,000 in 2019. Urban areas hold vast potential for solar energy: 90% of European rooftops are currently unused, offering a total estimated installed capacity of around 80 GW.

The potential is estimated to be 680 TWh, or 25% of current electricity consumption, according to the European Commission's Joint Research Centre (JRC)⁶. Decentralised solar installations (15.1 GW) are forecasted to exceed utility-scale installations (14.2 GW) by 2028. Building roofs and facades (building-integrated photovoltaics) in urban and non-urban areas will become more attractive in the future, and several cities have already initiated pilot projects. New applications for PV modules include building-integrated PV, agriphotovoltaics, vehicle-integrated PV, floating PV and road-integrated PV. New hybrid solutions are also being installed. It is estimated that Europe could generate 25 GW of capacity using inland waters and 45 GW from the sea⁷. Considerations of energy autonomy and energy diversification, will show in how far large-scale projects like Desertec will experience a revival.

Europe has traditionally been a leader in R&D on PV. Fraunhofer Gesellschaft, for example, developed the world's most efficient solar cell⁸. Yet, when it comes to solar PV production, the EU has fallen behind, with no European company currently among the top ten producers. Hopes are pinned on new materials, such as bi-facial PV modules, and new PV technologies, such as perovskite solar cells, that can further increase efficiency but also strengthen European competitiveness.

EUROPEAN COUNTRY					
GERMANY	SPAIN	POLAND	NETHERLANDS	FRANCE	
POSITION (2022)	1 ST	2 ND	3 RD	4 TH	5 TH
NEW INSTALLED CAPACITY	7.9 GW	7.5 GW	4.9 GW	4.0 GW	2.7 GW

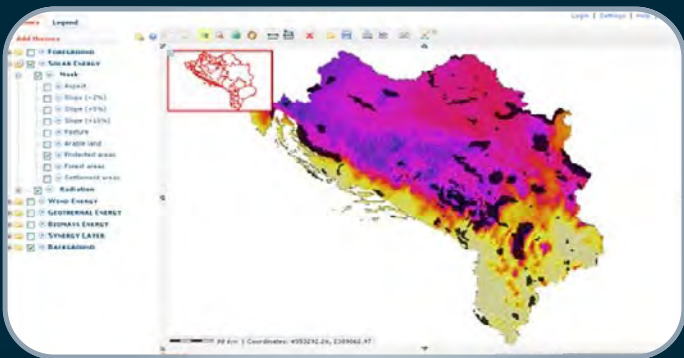
4. NEW REPORT REVEALS EU SOLAR POWER SOARS BY...
5. PRODUCER-CONSUMERS
6. OCEAN ENERGY: TECHNOLOGY MARKET REPORT...
7. TREND PAPER FOR INTERSOLAR EUROPE: FLOATING PHOTOVOLTAICS...
8. FRAUNHOFER ISE DEVELOPS THE WORLD'S...

Solar energy sector trends and needs

The energy transformation is characterised by increasing decentralisation, digitalisation and electrification, which is driving the need for data and Energy-as-a-Service (EaaS) and Energy-Data-as-a-Service (EDaaS) models. Weather, environmental data and land information are becoming key factors, even in real time. The following space-related use cases have been identified as being of the greatest commercial relevance.

LOCATION SCOUTING AND DUE DILIGENCE

Finding a location that maximises output potential is a key factor in solar energy production at both commercial and private levels, at utility scale, and as a prosumer. Location assessment will become more diversified and will include deserts, rooftops or water bodies. Rooftops need to be assessed for inclination angles or obstacle obstruction, among other factors. Data plays a crucial role in deciding where to place solar systems, since mapping of remote locations can provide historical and forecasted data on each location's potential. Factors considered include solar irradiance, air quality and cloud coverage, as a lack of sunlight can limit efficiency, affecting the economics of solar projects. Banks and investors need to understand the bankability of planned new projects. With new financing options such as solar leasing and power purchase agreements, this need is further increasing.



Balkan Renewable Energy Potential mapped by GeoVille⁹

SYSTEM PLANNING AND FORECASTING

With a growing number of small power producers, the need for mapping and planning of new energy sources is important both in terms of productivity and the socioeconomic environment. Governments and energy operators need to locate optimal areas for new power installation, taking account of mid- and long-term energy needs and supply. Real-time weather data, and especially solar irradiance and clear-sky information, are becoming more important, with changing feed-in tariffs and stronger market pressure. Solar power requires planning and forecasting to ensure that its energy is used more efficiently. Flexibility will also be provided by storage facilities, active demand management and increased grid interconnectivity. With a greater number of prosumers in the market, multidirectional flows of energy and information are required.



Installation of a solar power plant, container battery energy storage systems

MAINTENANCE AND CONNECTIVITY

With the diversification of solar PV applications, communication requirements are increasing for remote areas, and for water bodies in the case of floating PV. Utility-scale solar farms face high cost pressures, and regular site monitoring and analysis is important to identify any anomalies in production.

Predictive, automated maintenance is required to detect inefficiencies before equipment needs to be replaced. Drones may need to be directed to clean solar panels to ensure they retain their full functionality (via remote thermographic imaging of facilities). Maintaining the installation is crucial to ensure the longevity and optimal performance of the sites. Workers and drones often work together to clean sites, inspect, test and perform repairs.



Photovoltaic installation maintenance

ENERGY EFFICIENCY, ELECTRIFICATION, AND PROSUMERS

Prosumers and the increasing electrification, refers to that active end-use sector who not only buys energy, but produces, stores, and eventually sells the created energy into the network, greatly increasing the load on distribution networks. Smart meters will support managing devices, balance consumption, and increase energy efficiency of electrified sectors.



Distributed solar PVC

ENVIRONMENTAL IMPACT AND PROTECTION FROM NATURAL HAZARDS

New PV installations, such as floating or agro-PV, have to show their harmfulness to their local environment during pilot phases as well as mid- and long-term use (e.g. existing habitats, biodiversity). Moreover, installations should be protected against natural hazards. The vulnerability of the site must be assessed by identifying risk zones and by monitoring external threats.



Solar Farm

9. GEOVILLE: GEOVILLE INFORMATION SYSTEMS AND DATA...



Added value of the space sector

Sixty years ago, solar cells brought about a coming together of the space and energy sectors for the first time. Today, the predicted increase in new installations, the need for greater efficiency, and the dependency on environmental information is opening up new commercial and scalable opportunities for space-based applications and services.

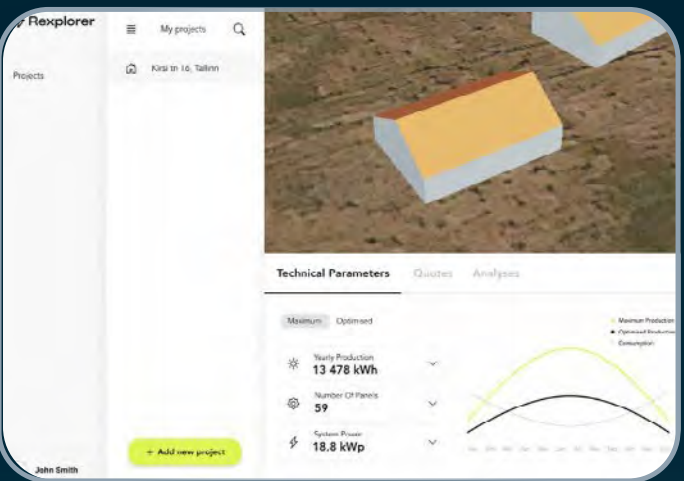
Geospatial data is of critical importance in identifying suitable locations by **mapping solar geometry** (solar noon, daylight hours, hourly solar angles from the horizon), radiation, insolation, clear-sky days and illuminance. Publicly available data, from Sentinel-4 for example, serves as the basis for many downstream services for the solar sector, such as location scouting, planning, monitoring, efficiency improvements and the integration of solar energy systems. This information forms the basis for Copernicus Atmosphere Monitoring Services¹⁰. This space-based data also feeds into various tools such as the **Photovoltaic Geographical Information System (PVGIS)** offered by the JRC and the Global Solar Atlas, administered by the World Bank and developed by Solargis. It offers, among other things, visualisation of global solar resources, power potential and yield calculations and feeds into other tools such as the Global Solar Atlas for Renewable Energy by IRENA and RETScreen¹¹.

Various start-ups have been emerging to provide further services to the growing number of new customers. Rexplorer¹², a company incubated by the ESA BIC¹³ Estonia, generates digital twins of rooftops for the installation of solar PV. The company combines 3D modelling, satellite data and on-demand API services for solar energy developers and other partners such as smart city energy planners.



Sentinel-4 measuring, among others, Earth and Solar irradiance

The artificial intelligence is trained to use any type of building satellite imagery and recognise obstacle objects to then determine, with a high level of accuracy, the scalability of the energy potential in that specific location. Solutions are also being developed by Glint Solar¹⁴, which uses satellite altimetry and multispectral imagery along with machine learning to identify and evaluate the best sites for floating solar power, taking into account engineering criteria, local climate conditions, logistics considerations and more (ESA BIC Norway).



Rexplorer indicating rooftop potential based on the inputted household address

Reveal AI¹⁵, for its part, exploits satellite data from ESA BIC Hessen (Germany), while Solartechno¹⁶ offers a modular, autonomous, plug-and-play photovoltaic electricity product based on space technology. Another example of technology transfer is Polar Developments¹⁷, a company that uses ESA-patented modular deployment technology and offers near-instantaneous high-capacity photovoltaic generators.

- 10. COPERNICUS ATMOSPHERE MONITORING SERVICES...
- 11. GLOBAL SOLAR ATLAS...
- 12. REXPLORER...
- 13. BUSINESS INCUBATION CENTRE...
- 14. GLINT SOLAR...
- 15. REVEAL AI...
- 16. SOLARTECHNO...
- 17. POLAR DEVELOPMENTS...



START-UPS



Examples of companies supported by ESA

With the increasing numbers of distributed solar panels being installed, there is a growing **need to map commercial and private solar panels and capacity** to improve grid planning and evaluate policy measures or identify gaps. The use of Sentinel-2 data, complemented by private constellations such as SPOT from Airbus¹⁸, has resulted in successful synergies when using innovative data science models.

Solar panel management software and tools are on the rise in a context of increasing competition. While RETScreen is one of the best known, other new solutions are also emerging to improve planning, forecasting, maintenance and inspections. GNSS and IoT communication via satellite can support drones and other remotely piloted aircraft in automatic photovoltaic plant inspection and data exploitation¹⁹.



Astradyne's SolarCube²⁰

The **solar energy transition is also taking place in space**, as spacecraft rely on solar energy. The Sun has greater energy potential in space, where it is the main source of energy²¹. Space-based solar power (SBSP) projects are among the most inspirational initiatives as they aim to harvest unlimited green energy from space and transmit it wirelessly back to Earth. Solar energy potential is over ten times greater in orbit than on Earth due to higher solar illumination, unfiltered by atmospheres, and non-dependence on weather conditions. SBSP can thus balance out the intermittent nature of other terrestrial renewable sources. Such systems have the potential to provide 100s of GWs of constant power to Earth at a build cost comparable to large terrestrial engineering projects.

It is for this reason that ESA has established the SOLARIS R&D initiative to mature SBSP concepts and technology by 2025. A decision on whether to embark on a full European development programme will be made, aiming to deliver clean, affordable, continuous, abundant and secure energy, 24 hours a day, seven days a week, during the 2030's. "The concept has been around for decades and is expected to be feasible because the building blocks are already there", says Sanjay Vijendran, Head of the SOLARIS initiative. He believes that Europe already has all the required technological expertise, but more advancement is needed in technologies such as radiofrequency power beaming, large modular antennas, large-scale robotic in-orbit construction and manufacturing, low-cost solar cells, and more to confirm both technical but also economic feasibility.

In conclusion, renewables are on the rise and solar leads the green energy mix, giving place to high investments in R&D, new technologies and environmental crisis solutions. This sector is expected to continue growing resulting in interesting commercial opportunities for space related companies.

- 18. ICT INSTITUTE | USING AI TO COUNT ALL THE SOLAR...
- 19. AUTOMATIC PHOTOVOLTAIC PLANT INSPECTION...
- 20. HOMEPAGE - ASTRADYNE...

21. New innovations are also being developed for spacecraft: Astradyne's SolarCube is an origami-inspired solar panel characterised by a high stowed-to-deployed surface ratio and lightness.





Space for renewable energy

**Space commercialisation
for wind energy**

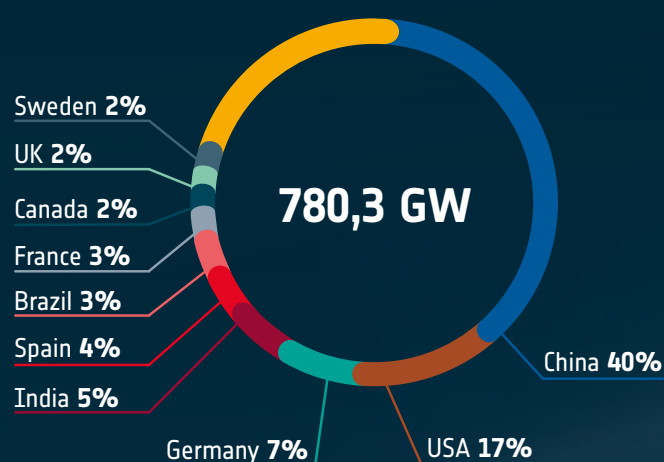


Space commercialisation for wind energy

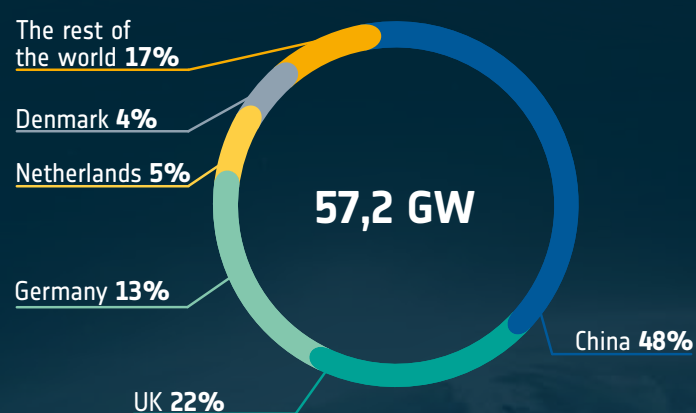
The rise of the wind energy sector

Renewable energy is a strategic sector on the rise worldwide, with most countries striving for green and independent energy sources. In terms of newly added capacity, wind energy is the **second-fastest growing green energy source**, just behind solar¹. In 2021, 93GW of global newly installed energy capacity came from wind, of which 21GW was generated offshore.

In 2022, this amounted to a total of **780GW onshore** and **57GW offshore** energy capacity from wind assets². While onshore wind is the most technology-ready and cost-effective option at present, accounting for most wind power production, offshore wind generation has increased more than sixteenfold since 2010.



Ranking of accumulated terrestrial wind power by country, 2022²



Ranking of accumulated offshore wind power by country, 2022²

1.5-S

The **1.5°C Scenario (1.5-S)** describes an energy transition pathway aligned with the 1.5°C climate ambition - that is, to limit global average temperature increase by the end of the present century to 1.5°C, relative to pre-industrial levels. It prioritises, readily available technology solutions, which can be scaled up at the necessary pace for the 1.5°C goal.

IRENA's 1.5°C scenario (source: IRENA's World Energy Transitions Outlook report)

The increasing installed capacity reflects the high level of interest in offshore wind, with fixed foundations being the **most mature technology among offshore renewables**³. According to the International Renewable Energy Agency's (IRENA) 1.5°C scenario³, offshore wind could reach a total installed capacity of around 382GW by 2030 and around 2,002GW by 2050³. Nevertheless, the marine environment presents significant engineering obstacles to this expected growth.

1. NET RENEWABLE CAPACITY ADDITIONS BY TECHNOLOGY...
2. GRÁFICOS ANUARIO EÓLICO 2022 – ASOCIACIÓN EMPRESARIAL...
3. WORLD ENERGY TRANSITIONS OUTLOOK (IRENA.ORG)...

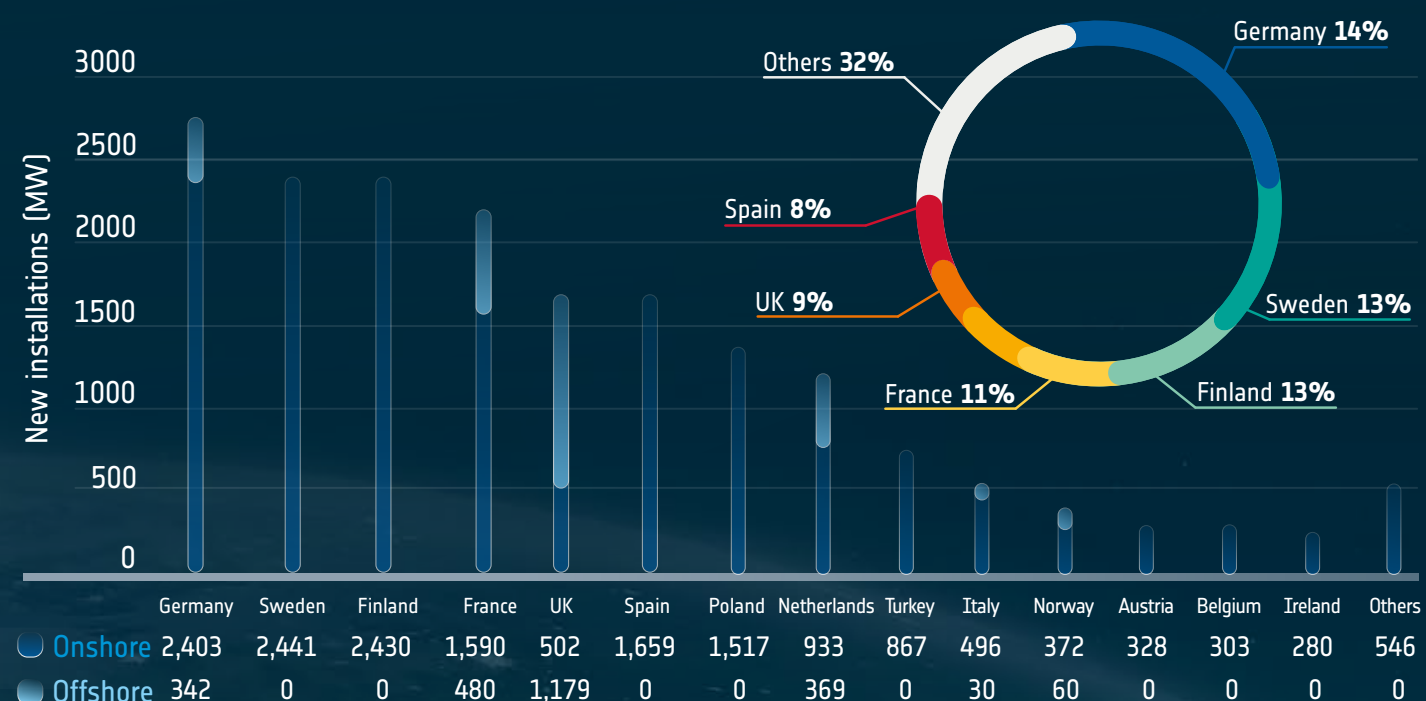
European wind energy landscape and players

In mid-2022, total installed wind power in Europe amounted to **220GW**, of which 28.3GW was offshore⁴. The European rankings for total accumulated installations are topped by Germany, followed by Spain, the UK, France and Sweden⁵, with Germany and Spain ranking in the top five worldwide.

Onshore and offshore wind are set to grow further, with offshore **expected to increase to at least 25 times current capacity by 2030**⁵. The European Commission estimates that between 240 and 450GW of offshore wind power will be needed by 2050.

The question then arises: why does European offshore wind account for almost half of global offshore wind power? Large offshore wind projects in Europe have traditionally been

concentrated around the North Sea but are also being developed in the Baltic, Mediterranean and Black Seas, as well as in the Atlantic Ocean. The sector was pioneered by Denmark, which was behind the world's first commercial-scale offshore installation of 160MW back in 2002⁶. The world's largest offshore wind farm to date is the UK's Hornsea Project 2, with 1.39GW of capacity. However, SSE Renewables (UK) is currently building the 3.6GW Dogger Bank Wind Farm, which may surpass Hornsea 2⁷. In addition, France has four floating wind demonstration projects under development, and in Spain, Iberdrola is planning the first industrial-scale floating offshore wind farm with a capacity of 300MW, which will lead to the development of up to 2GW⁶.



New onshore and offshore wind installations in Europe in 2022 (source: WindEurope)



The 160MW Horns Rev (Horns Reef) offshore wind farm in Denmark

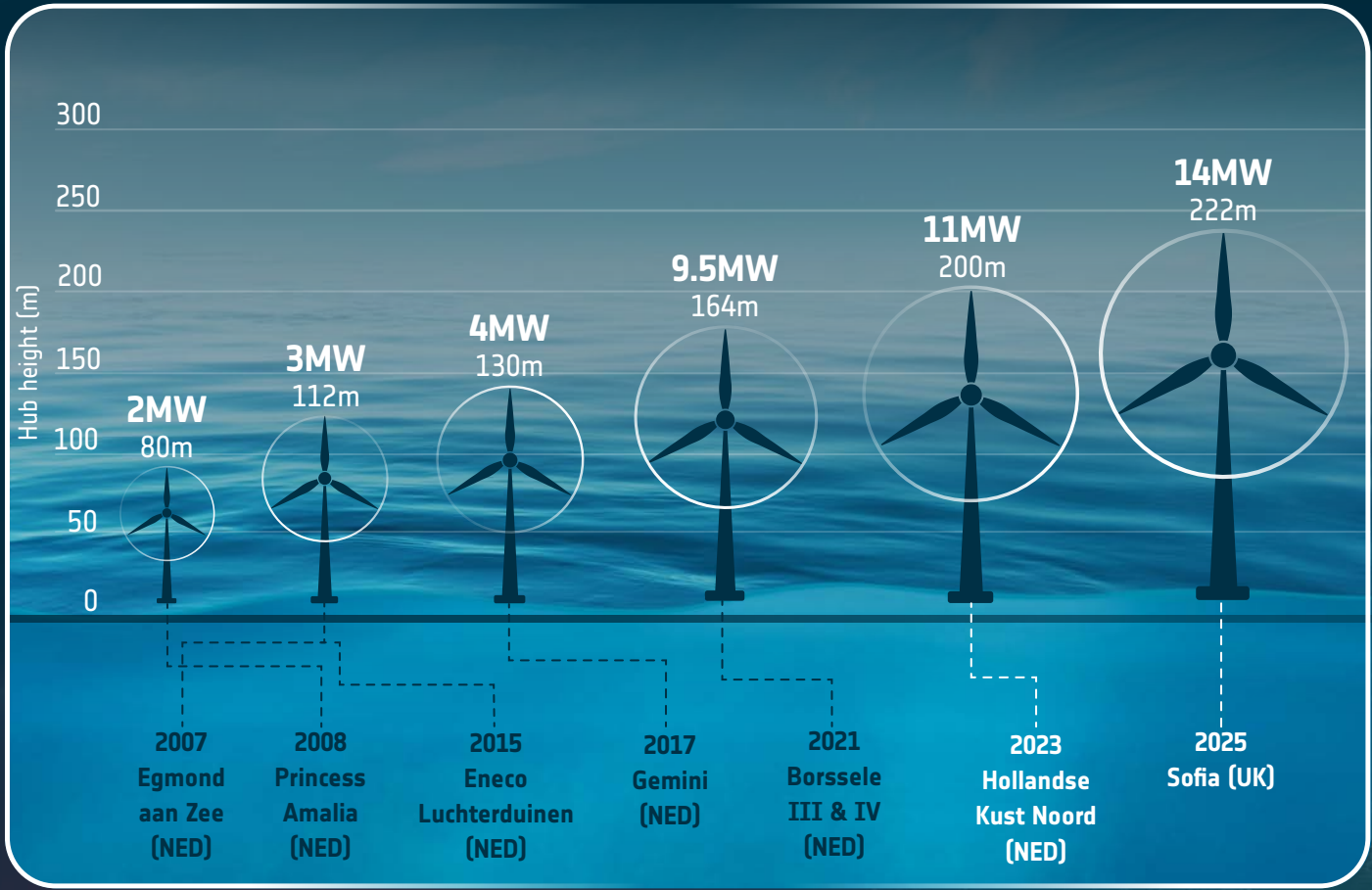
At the beginning of 2022, the highest total accumulated wind power ranking in Europe by company was led by Siemens Gamesa (14.79GW, Germany), followed by Vestas (4.92GW, Denmark) and Nordex Acciona Windpower (2.46GW, Germany)². Other major European offshore renewable players include Orsted (Denmark), RES (UK) and Vattenfall (Sweden). The future growth trajectory will depend on technology and cost evolutions and will be predicated on the right public policies and spatial planning.

4. GRÁFICOS ANUARIO EÓLICO 2022 – ASOCIACIÓN EMPRESARIAL...
5. OFFSHORE RENEWABLE ENERGY...
6. OFFSHORE RENEWABLES: AN ACTION AGENDA FOR DEPLOYMENT...
7. DOGGER BANK OFFSHORE WIND FARM | SSE RENEWABLES...

Wind power innovations are frequently being introduced in Europe as a result of intense R&D activity. **Floating wind turbines** are being developed, for example, that provide greater flexibility to move installations in accordance with wind patterns and ship movements, while avoiding high foundation installation costs. They also enable access to deeper waters without having a major impact on marine life. **Vertical blades** are also being developed and, in spite of their lower performance, are opening up new opportunities – they have no need for an orientation system and their generators can be located in more accessible areas, thus reducing maintenance costs. Urban wind energy is being tested as vertical turbines do not require great heights and are thus more adaptable to city environments. Airborne wind energy systems are also being explored. At the same time, **traditional wind turbines have been growing in height** in order to capture more energy and increase cost efficiency⁸. Research

into other wind energy technologies is being conducted at many European institutes such as TU Berlin, ETH Zürich, Fraunhofer IWES and ABB Corporate Research, and as part of the SkySails SkyPower100 project.

Furthermore, the development of renewable wind energy, both onshore and offshore, is **strongly supported by European governments** through new policies and various support schemes, notably under the European Green Deal⁹ and REPowerEU¹⁰. In particular, the EU Strategy on Offshore Renewable Energy¹¹ sets targets for an installed capacity of at least 60GW of offshore wind by 2030, and 300GW by 2050. European companies are world leaders in the manufacturing of key wind turbine components, as well as in the foundations and cables industry.



Growth in wind turbine size (source: Windpower Monthly)

8. OFFSHORE RENEWABLES: AN ACTION AGENDA FOR DEPLOYMENT...

9. A EUROPEAN GREEN DEAL (EUROPA.EU)...

10. REPOWEREU : UNE ÉNERGIE ABORDABLE...

11. FFSHORE RENEWABLE ENERGY (EUROPA.EU)...



Wind energy needs and trends

Multiple needs and trends are emerging in line with the rapid growth of the wind energy sector, most revolving around the need for historical and instant monitoring data, connectivity and wind predictions.

LOCATION IDENTIFICATION

It is crucial to accurately **identify the areas in which wind turbines can be placed in the most cost-effective manner**. This assessment is based, in particular, on the identification of wind corridors and locations with a low risk of rain-related erosion and minimal wind turbine wake effect. Moreover, a terrestrial wind park cannot be too close to urban areas. Offshore wind, on the other hand, requires consideration of the sea base, climate change fluctuations of wind, shipping activity and environmental impact.

BANKABILITY

Bankability estimates are made mainly through wind forecasts based on historical or in situ data. However, increased offshore activity makes data collection by buoy more difficult. The aim of such estimates is to identify appropriate locations with **enhanced cost competitiveness and low risk**. To reduce costs, companies can develop bigger turbines: one example is Vestas, which is developing a 15MW offshore wind turbine. Wind operators are also aware that a non-functioning turbine in the sea incurs greater costs than onshore, as the technology for offshore is more expensive due to higher installation, operation and maintenance costs.

EFFICIENCY INCREASES AND SYSTEM PLANNING

Data is essential in order to increase wind installation efficiency: through data, demand and supply can be managed and forecast on a local, regional and system level. On the demand side, mapping of the access to electricity in urban and remote areas is required, resulting in a time synchronisation for power generation and distribution. On the supply side, to increase efficiency on site, there is a need to mix digital data (models) with real-time in situ data in order to adjust the relative position of the blades and maximise the performance of the turbine. Planning is also required to achieve a balance between countries, networks and regions, as well as energy mixes.

MAINTENANCE AND COMMUNICATION

Wind parks can differ in terms of generators and technology, **making repairs and maintenance increasingly complex**. Optimising the park may require shutting down the first row of turbines, which tend to capture more wind overall, thus enabling the rest of the park to match the production levels of the first row so that all the turbines undergo mandatory maintenance at the same time. Moreover, inspection of turbines by drone are increasingly widespread, as the blades can be analysed using infrared thermal sensors to detect areas with humidity and internal cracks and to support cleaning activities. For offshore

installations, more **communication technology and operations planning** is required. Increasingly frequent extreme weather events and corrosion are some of the challenges resulting in a need for modern materials that are more resistant or methods for monitoring the condition of the infrastructure in order to plan and reduce the required maintenance.



Iberdrola's wind turbine drone inspection

TRANSMISSION AND DISTRIBUTION

To avoid incidents such as ground displacement that would prevent energy from being reliably transmitted and distributed, **wind installations require infrastructure monitoring**. Vegetation and weather event monitoring are also essential to reduce the risk of floods and soil movements, among other things. Moreover, as wind is an intermittent source of energy, it requires the use of a special kind of grid, namely a smart grid, to continually adjust supply to match demand thanks to a two-way flow of electricity and data.

ENVIRONMENTAL IMPACT MONITORING AND PROTECTION

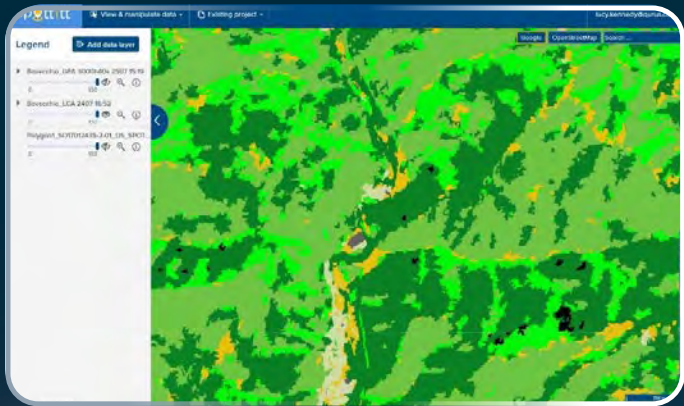
To approve a wind energy project, an environmental impact assessment must be performed. Throughout the project, it is also necessary to **perform ecosystem diversity monitoring and ensure protective measures**. Onshore installations should thus be optimised as much as possible, as the growth of a wind park requires a greater number of grid connections affecting both flying animals and vegetation. In the offshore sector, marine spatial planning is also required: turbines can interfere with sediment flows and produce marine litter, but can also act as artificial reefs.

Space sector added value

Wind energy provides opportunities and challenges in which the use of space technologies and data can play a significant role, mostly through Earth observation (EO), navigation and satellite communication. These will support and improve the information provided by in situ sensors and help manage the identification of locations for offshore wind parks and their operations and maintenance, as well as the coordination of surrounding transportation and fisheries.

ONSHORE APPLICATIONS

In the onshore sector, machine learning applied to EO space data mapping is being used to **support the identification of wind farm locations**. EO can be leveraged to evaluate the terrain slope and conditions, create digital elevation models or analyse wind resources through various indicators, including land cover information. ESA, through the Business Applications and Space Solutions (BASS) programme carried out through its Telecommunications and Integrated Applications (TIA) Directorate, has already carried out feasibility projects on such use cases. Spottitt¹², a start-up launched after its founder completed one such ESA-sponsored feasibility study, has for example developed a one-stop online portal, where energy operators can access high-resolution EO and non-EO data layers for wind park site selection in order to identify the optimal location based on a range of factors, including infrastructure location, land cover, slope and elevation and accessibility.



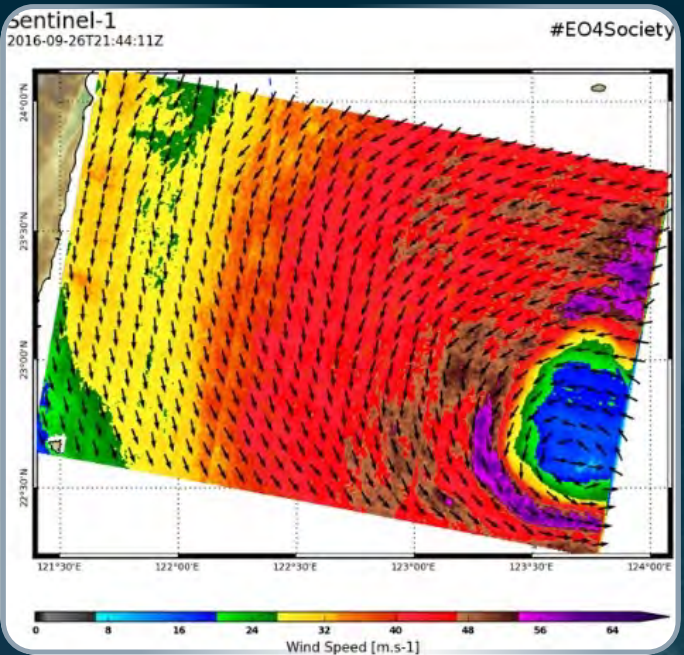
Spottitt land cover analysis

Moreover, as **the smooth operation of wind parks relies on constant data gathering**, high temporal resolution space data can be leveraged for that purpose. ESA, through its Business Incubation Centres (BICs), has for example successfully supported the Spanish firm Eolion¹³, which integrates global navigation satellite systems (GNSS), satellite images and 3D data with its wind turbine control algorithms and wind farm models to build new controls that increase wind energy reliability and production (2–3% additional energy).

Finally, operational expenditure for wind parks can increase when corrective or emergency maintenance is required. To **anticipate equipment failures**, EO-derived parameters can be leveraged for maintenance, for example by measuring rainfall to estimate turbine blade erosion and by modelling winds at various hub heights in comparison to surface winds.

OFFSHORE APPLICATIONS

Planning new offshore wind parks is a challenge as data is mainly collected using buoys, drones or various types of autonomous underwater vehicle (AUVs) using lidar, sodar or radar to gauge technical and environmental feasibility, considering aspects such as wind, depth, currents, seabed, wildlife, waves, salinity and icing. This planning stage can be lengthy and costly. Space technology has the potential to reduce such costs by providing real-time data from specialised satellites. For example, Europe has a long tradition of determining sea surface wind speed and direction through the wind-induced roughness of the sea surface as measured by satellites. Data is available globally and very frequently (several times daily), both at coarser resolution, through the MetOp series for example, or higher resolutions through Sentinel-1.



Wind speed derived from Sentinel-1 data over Typhoon Megi

The installation of offshore wind farms also presents immense challenges, with many huge parts that need to be installed with a high degree of accuracy out in the open ocean. Location and time data from Galileo GNSS can be used to ensure that turbine parts are positioned and installed accurately: this is the value proposition of Bremen start-up Flucto¹⁴, a graduate of the ESA BIC incubation programme.

12. GEOSPATIAL ANALYTICS EASY AND EFFECTIVE...
13. EOLION – LA ENERGÍA EÓLICA DEL FUTURO...
14. ABOUT FLUCTO...



Space data also provide **data forecasts for planning, monitoring and optimisation of operations**. Examples of the use of EO to support offshore wind production were recently showcased in the ESA EO for Society Atlantic Regional Initiative¹⁵. A dashboard was created¹⁶ for wind farm design and operations, providing data relating to weather windows for offshore operations planning, wind resource, wind turbine wake effect and rain erosion of wind turbine blades¹⁷. Through ESA BASS, the MESPAC¹⁸ project has also proven that EO data, when integrated with advanced physical models and AI algorithms, can help wind developers to continuously monitor their sites of interest without the typical risks and issues encountered during offshore surveys. EO data can further increase offshore wind equipment durability and survivability: the SNAPPED feasibility study, launched by ESA in March 2021, will for example use satellite EO to provide weather and sea forecast data for the optimisation of the adaptive Load Reduction Device (LRD) for floating offshore wind mooring

systems. Similarly, the Danish company DHI has received support from the ESA InCubed programme for its SiteObserver activity¹⁹. This service will provide satellite-based surveillance for offshore wind farms, including data on seabed and coastal dynamics, vessel traffic, turbine direction and sedimentation patterns.

EO can also support environmental monitoring and protection through monitoring of sea pollution, analysis of marine habitats and coastal ecosystems and detection of harmful spills, among other things.

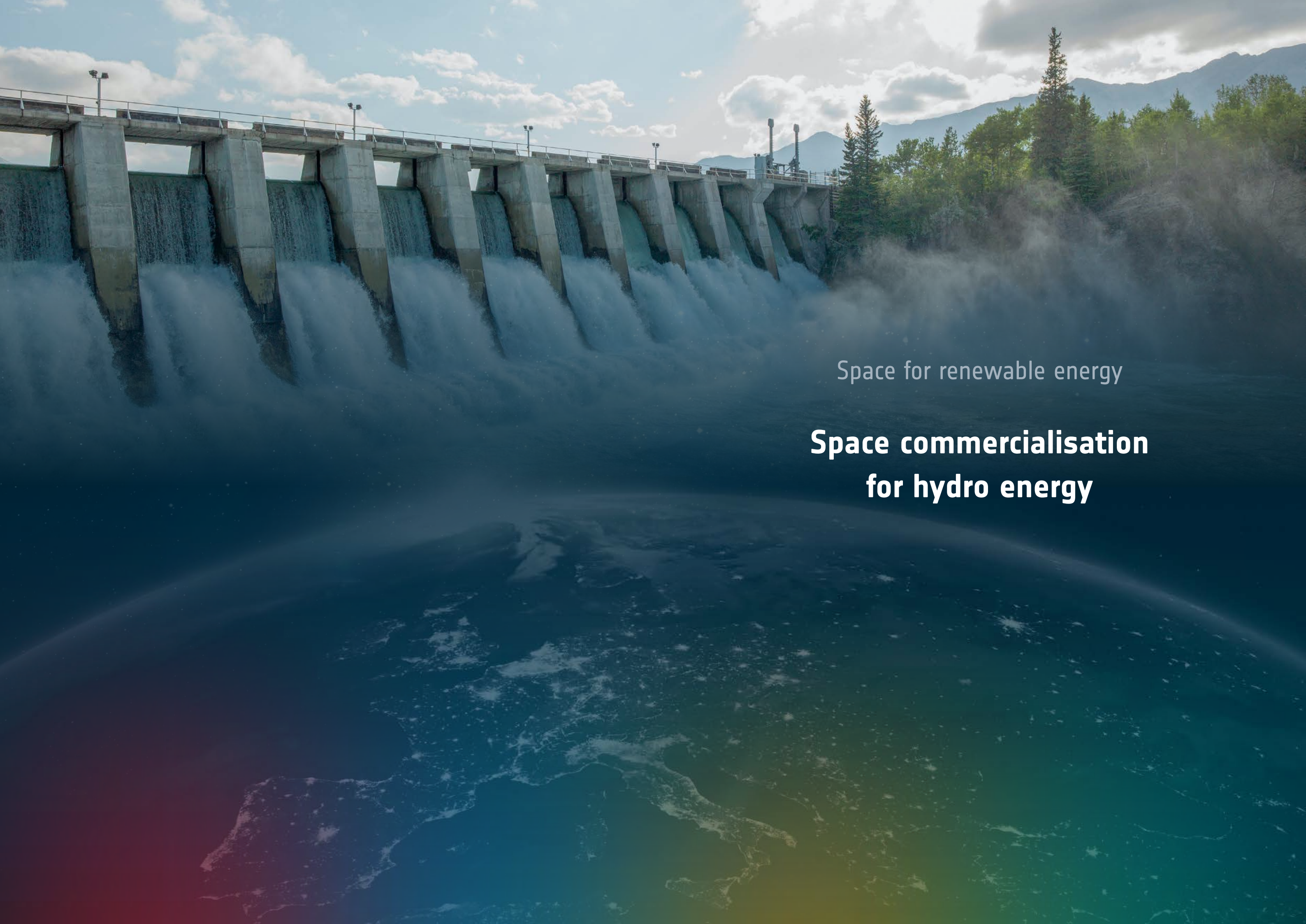
Finally, **offshore wind farms require platforms to land communications that are constant, reliable, low in latency and resilient to harsh weather events** such as strong winds and salt spray. As low-Earth orbit (LEO) constellations enter operation, they bring higher levels of resiliency as well as lower latency.



Overall, wind energy plays a key role in the green energy transition, resulting in more R&D projects and ultimately a growing market and thus providing **new commercial opportunities for space-based services**.

15. ATLANTIC REGIONAL INITIATIVE – EO SCIENCE...
16. GLOBAL ATLAS (IRENA.ORG)...
17. [HTTPS://EO4SOCIETY.ESA.INT/PROJECTS/ATLANTIC...](https://eo4society.esa.int/projects/atlantic...)
18. MESPAC | ESA BUSINESS APPLICATIONS...
19. SITEOBSERVER | INCUBED (ESA.INT)...





Space for renewable energy

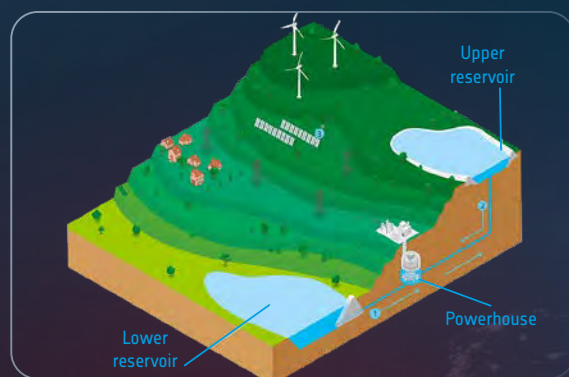
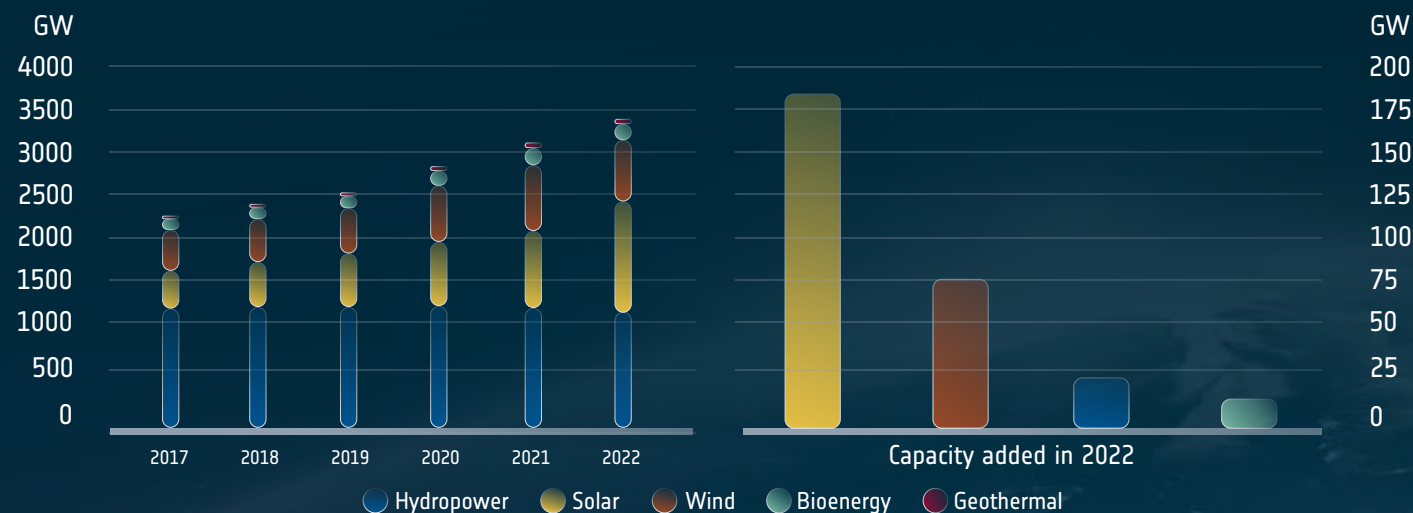
**Space commercialisation
for hydro energy**

Space commercialisation for hydro energy

Introduction to hydro energy

Humanity's oldest source of renewable energy currently plays a pivotal role in the energy supply of over 160 countries worldwide. **With 4,252 TWh generated in 2021**, hydropower makes the largest contribution to total renewable electricity generation (37%), coming right after coal and natural gas¹. Nonetheless, its growth rate has been relatively slow in comparison to solar and wind energy largely due to environmental and social impacts, complex permit acquisition processes and long construction times.

To reach carbon neutrality by 2050, hydro energy has a major role to play. It offers three distinct advantages when it comes to clean energy generation. Firstly, hydropower is one of the most **cost-effective** ways of generating electricity. Secondly, dams can provide **multiple benefits** as their infrastructure can be used to supply clean water for homes and agriculture, for instance, or to mitigate the impact of increasingly frequent extreme weather events, such as floods and drought.



Closed loop PSH illustration from IHA³

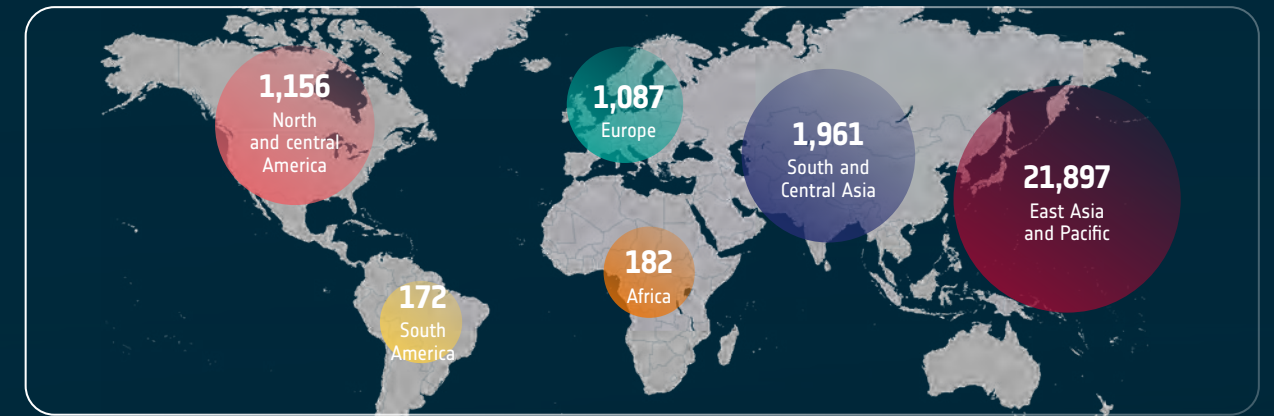
Lastly, it **provides flexibility and can be stored**. No back-up is required and on account of its reliability, hydropower can adapt to the daily and seasonal fluctuations of the next two largest renewable sources (solar and wind). Pumped hydropower storage (PHS) especially offers major potential in supporting the rapid growth of solar and wind energy as it absorbs and releases energy on demand.

The East Asia and Pacific region is the fastest-growing hydro energy market on account of the major investments that have been made there.

1. HYDROPOWER STATUS REPORT SECTOR TRENDS AND INSIGHTS...
2. RENEWABLE CAPACITY HIGHLIGHTS...
3. LET'S GET FLEXIBLE – PUMPED STORAGE...

In 2021, the countries with the greatest installed hydropower capacity were China (29%), Brazil (8%), the United States (7%), Canada (6%), Russia/India/Japan (4%) and Norway (2%). Developing countries currently have most of the world's untapped potential for hydropower and remote rural areas in these countries could, for instance, be served by off-grid and mini-grid hydro systems.

International and multi-stakeholder cooperation is playing a significant role in preparing the future of hydro energy by fostering collaboration, financing and sustainability compliance. Examples of this cooperation include the International Renewable Energy Agency (IRENA) or the International Hydropower Association (IHA).



New hydropower installed capacity by region in 2021 (mW)

Overview of the European hydropower market

Owing to its technologically developed and mature hydro energy industry, Europe is a leading force in the development, innovation and export of hydropower. In 2021, hydropower installed capacity amounted to 255 GW, representing around **one-fifth of the world's hydro capacity**, and 44 GW of this total consisted of PHS⁴. Hydropower also accounted for 32% of the European Union's renewable electricity production and provided 12% of the EU's electricity⁴.

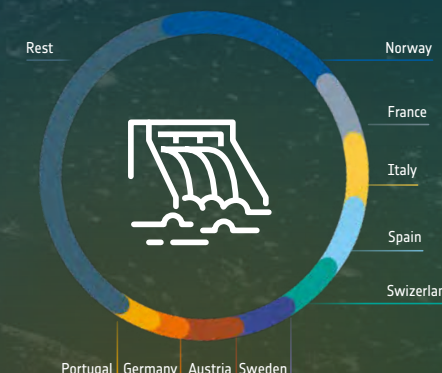
In absolute terms, Norway is Europe's largest hydro electricity supplier (99% of its own electricity comes from hydropower)⁵, mainly through Statkraft, a state-owned utility that is also one of Europe's leading hydropower companies. France comes a close second (main provider EDF), followed by Italy (Enel SpA) and Spain (home to Cortes, Europe's largest PHS plant).

In relative terms, Switzerland owes a very substantial portion of its renewable energy generation to hydropower (80% capacity in

2021, including marine), as for Romania (59%), Croatia (64%), Austria (66%) and Latvia (86%)⁶.

Since 2000, new large-scale hydropower developments have been few and far between in Europe, with 40% of European hydro infrastructure now more than 40 years old. Given that major refurbishment is needed after 45–60 years on average, a **large share of the hydro infrastructure will urgently need to be refurbished** in the coming years.

At the same time, small-scale and hybrid hydropower solutions are emerging, and are expected to grow in Europe in the future. **Hybrid plants combining solar and wind energy** generation offer controllable and flexible electricity generation, reduce transmission interconnection costs and can lower upfront costs related to permits, site acquisition and engineering⁷. **Small-scale plants** help to reduce the negative social and environmental impacts of large projects. The reservoirs of large plants lead to methane emissions, the displacement of people, sedimentation and disrupted stream dynamics⁸. Small plants, however, have no such reservoirs, and therefore have a minimal impact. Finally, other technologies such as closed-loop schemes or fish-friendly turbines are being considered to achieve compatibility with environmental restrictions expected by the EU.



Hydropower installed capacity by country in Europe⁴

4. 2022 HYDROPOWER STATUS REPORT...
5. HYDROPOWER IRENA...
6. IRENA OVERVIEW...
7. HOW HYBRID PV TECHNOLOGIES CAN CONTRIBUTE TO...
8. HYDROPOWER (SMALL-SCALE)...

Hydro energy needs: harnessing the potential of space technologies

Today in Europe, the need to reconsider established systems and processes in the hydro energy market is more urgent than ever before. Refurbishment options that can maximise the potential for efficiency while supporting small-scale and hybrid projects as well as addressing environmental aspects are very much in the spotlight. With these needs, fresh potential is emerging for space-based solutions in Europe as well as in the rest of the world.

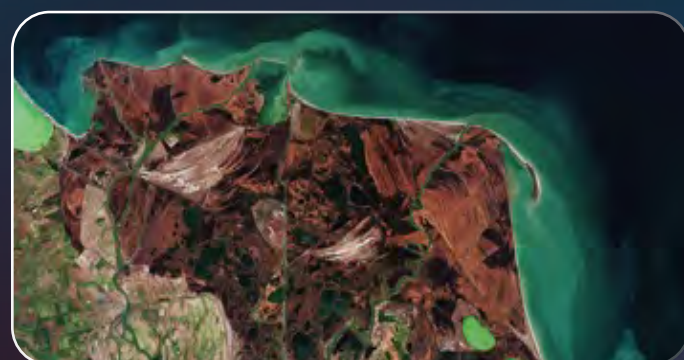


LOCATION-SCOUTING FOR NEW AND DIFFERENT TYPES OF HYDROPOWER PLANT

Optimal locations for new large and small-scale plants must be identified to support the growth targets for hydro energy. Satellite images can permit water resource assessments and thus help find locations with high energy generation potential where the environmental impacts caused by rerouting or damming the water flow would be minimal⁹. Hybrid plant locations could also be found by combining solar, wind and hydro Earth observation technologies.

IMPROVEMENT OF ELECTRICITY GENERATION FORECASTING

Flexibility is a key advantage of hydroelectric plants, and can be maximised through improved prediction. Earth observation (EO)-based forecasts offer considerable potential for the provision of hydrological and hydrometeorological modelling through a data assimilation scheme. EO-derived parameters include runoff estimates, precipitation and evaporation, soil moisture, river discharge and snow-related insights. Snow strongly influences management decisions as many plants are situated in mountainous regions. Currently, snow water equivalent (SWE) data is obtained through measurement campaigns that are expensive and involve safety issues due to avalanche risks.



Another advantage of satellites is that they enable long-term

data collection, which can help identify trends and patterns. These can be coupled with machine learning or data assimilation to improve prediction still further.

BANKABILITY

New plants require long-tenor loans and their construction typically poses higher risks, making them less attractive for private investors who prefer a rapid and secure ROI¹⁰. Accurate forecasting could help improve the bankability of planned new projects, leading to an overall increase in investment in hydro energy through public-private partnerships.

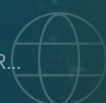
CLIMATE CHANGE AND INFRASTRUCTURE MONITORING

Real-time data on the structural health of dams to detect potential issues in their infrastructure can increase a site's safety and make it possible to take prompt action. EO data collection is suited to being performed more frequently and is cheaper in comparison to in-field measurements. Both methods can, however, be used simultaneously for optimal results, as seen, for instance in Enel Green Power's GPS Hydro project, which is based on the precision satellite positioning provided by the Global Navigation Satellite System (GNSS)¹⁴. Drones can also work in tandem with satellite images for closer inspection, providing a faster, safer, cheaper and more versatile alternative to traditional techniques such as scaffolding.

Space technology can also be used to map exposed and vulnerable assets for risks of hydrometeorological hazards (e.g. floods) or geo-hazards (e.g. landslides, terrain deformation) through synthetic aperture radar (SAR) data from Sentinel-1 or optical images from Sentinel-2¹¹. Due to climate change, these risks are increasing rapidly.

Researchers have underlined the importance of sediment levels when it comes to hydropower. Sediment limits the capacity of a reservoir's annual storage volume by an estimated 0.6% approximately and damages the dam¹², leading to revenue loss and an increased risk of flooding. A rising number of researchers and companies in various countries have been analysing hydropower plant sedimentation using satellite data from various sources such as Landsat, Sentinels or the China-Brazil Earth Resources Satellite (CBERS)¹³.

9. SATELLITE DATA APPLICATIONS FOR SUSTAINABLE...
10. THE CHANGING ROLE OF HYDRO POWER...
11. SECURITY THAT COMES FROM SPACE...
12. → EO4SD – EARTH OBSERVATION FOR SUSTAINABLE...
13. RIVER SEDIMENTATION CHALLENGES FOR HYDROPOWER...
14. FURTHER DEVELOPMENT OF SMALL HYDROPOWER...



MONITORING AND REGULATING ENVIRONMENTAL AND SOCIAL IMPACT

The World Wildlife Fund (WWF) has raised the alarm about the destructive impact of hydropower plants on biodiversity and rivers. More than 150 NGOs have already signed a manifesto calling on the EU to redirect its subsidies and public financing from building new hydropower plants towards refurbishing existing ones, for instance¹⁵. Potential negative environmental impacts must therefore be **monitored**. Research must be conducted on the processes by which organic material builds up behind dams, decomposes and removes oxygen from the water,

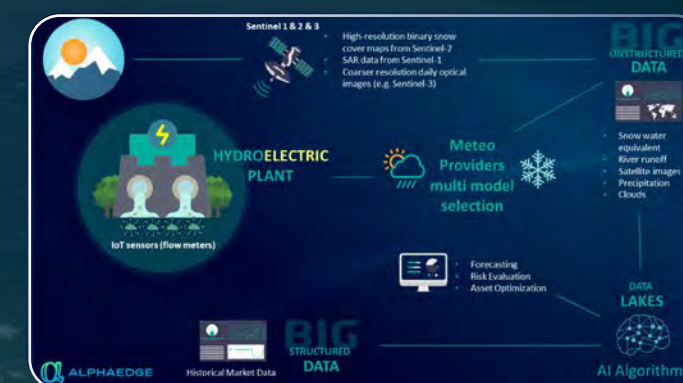
thereby killing plants and animals, and methane emissions from submerged vegetation must also be analysed. Finally, strict and transparent **sustainability criteria must be set**. The International Hydropower Association (IHA) launched the Hydropower Sustainability Standard in 2021 to rate and certify projects based on their sustainability compliance, which could potentially be monitored by EO. Negative social impacts such as population displacement or livelihood changes are of major importance, but are barely researched. A better understanding of these impacts could help mitigate them through new approaches and strategies. Satellite imagery offers significant potential in terms of analysing these phenomena.

The role of the space sector in Europe today

Space assets, especially EO, play an important role in the economic and environmental prospects of hydropower plants. ESA supports projects that aim to tackle existing and emerging needs, including forecasting and bankability, as well as climate change, infrastructure and environmental monitoring.

COMPLETE SOLUTIONS FOR HYDROPOWER COMPANIES

Alphaedge, supported by ESA BIC Austria, aims to provide real-time **forecasting, risk evaluation and asset optimisation** for hydropower plants¹⁶. It uses artificial intelligence on unstructured big data from EO images collected by Sentinel-1, -2 and -3 (e.g. of snow water equivalent, river runoff, satellite images, precipitation, clouds) coupled with Internet of Things (IoT) sensors and structured historical data.



Together with ESA's Business Applications Programme, the Norwegian start-up EDInsights can **map and monitor the surface water and volume of large to medium-sized reservoirs and lakes**¹⁷. The approach combines radar and optical satellite data from Sentinel and Radarsat satellites with machine learning and cloud processing. EDInsights is also the prime contractor for the WaterInfo project which uses radar images from the Sentinel-1a/b satellites and measurements from the Sentinel-2a/b satellites to monitor changes in the water resources of individual lakes and reservoirs. It aims to **optimise hydropower production planning while improving price predictions and market analysis**.

Finally, the DeFROST project by WeGaw uses Sentinel-2 data to provide hydro energy companies with more accurate snow-based forecasts to improve their planning¹⁸.

NEW RESEARCH RELATED TO HYDROPOWER PLANTS

ESA is funding research activities such as Fluvisat to investigate the potential use of satellite-collected video imagery to provide accurate and timely quantification of **water movements and river flows**¹⁹. Similarly, RIDESAT aims to develop a satellite-based river discharge product for small to large rivers through a novel synergistic utilisation approach of three special sensors (altimeter, optical, and thermal).

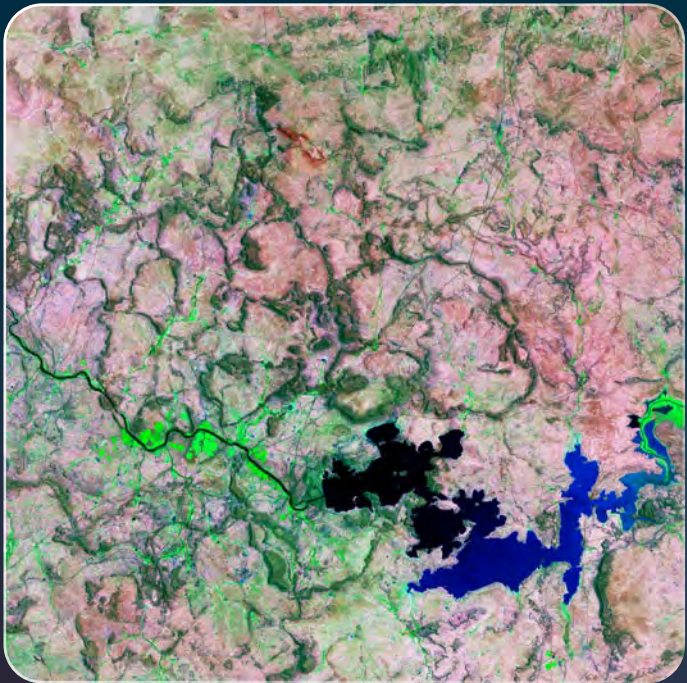


15. HYDROPOWER IS DESTROYING EUROPE'S RIVERS...
16. BIG UNSTRUCTURED DATA AND SPACE...
17. SPACEBORNE ANALYTICS FOR HYDROPOWER...
18. WE HELP YOU OPTIMIZE ...
19. EO SCIENCE FOR SOCIETY...



STREAM has investigated river runoff trends. More recently, RIDESAT and STREAM were merged into STREAMRIDE to improve river discharge estimates further²⁰. Finally, ESA's large-scale Soil Moisture and Ocean Salinity (SMOS) mission could help increase the accuracy of hydropower forecasting models by improving our understanding of specific parameters they use, such as soil moisture, which is driven by evaporation, infiltration and runoffs.

As stated previously, snow studies are important for the sector's planning capabilities, and new initiatives to monitor **SWE** have emerged. The eo4alps snow project uses high-resolution optical and radar EO from Sentinel-2, SAR data from Sentinel-1 and coarser-resolution daily optical images from Sentinel-3²¹. EOMAP²² together with Snowcap²³ and the Finnish meteorological institute, combine Sentinel-1 SAR data with snow models based on meteorological data to derive SWE estimates. These will provide highly accurate power generation forecasts for hydropower plants. While the companies are currently preparing for the demonstration study starting this September, potential customers such as Enel have already demonstrated their interests for such innovations. Alongside SWE, EO-based Fractional Snow Cover (FSC) mapping demonstrates strong result for hydrological modelling. The Norwegian Computing Center under the project NVE Copernicus 2, using Sentinel 3, has tested and is now developing an operational solution using deep learning AI technic to map FSC. PRODEX projects Snow Model for Sentinel is also using Sentinel 2 and 3 optical observations to develop a radiate-transfer-model (RTM) which can be used to derive snow properties such as grain size, impurities, surface temperature. These are valuable inputs for advanced distributed hydrological models to predict run-off more accurately.



Sediment analysis: Copernicus Sentinel-2 images of Gariep Dam sediment analysis²⁴

The impact of sediment on the storage capacity, lifetime and operating costs of reservoirs has triggered the emergence of new projects. The EU-funded HYPOS project²⁵ uses optical sensors from Sentinel-1, Landsat and Planet to evaluate new hydropower sites or manage existing ones by focusing on sediment-related parameters. Similarly, EOMAP uses high-frequency PlanetScope data provided by ESA to analyse sediment levels triggered by flushing events²⁶.



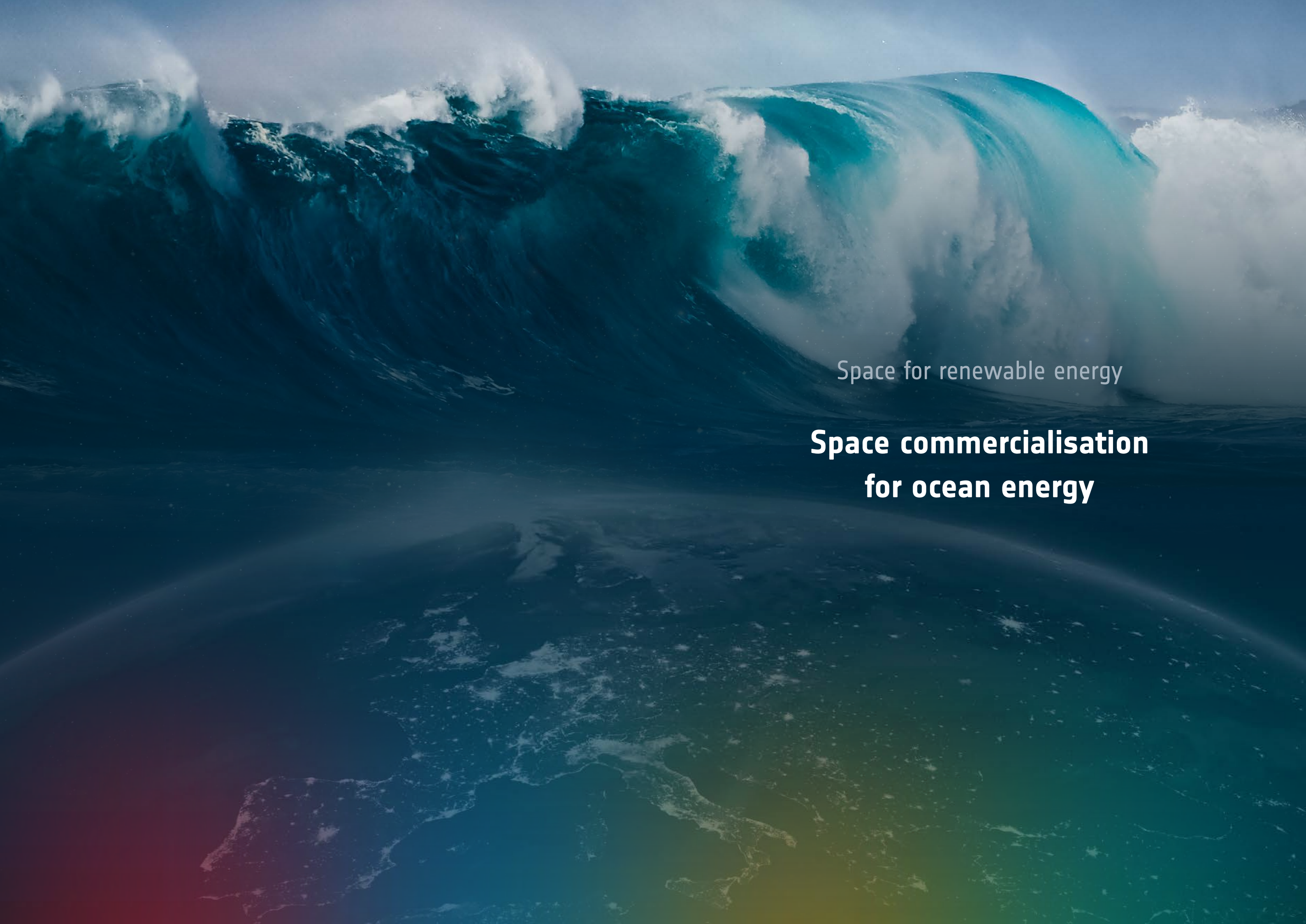
HydroGNSS satellite

In addition, new satellite data sources are being developed, including ESA's HydroGNSS mission. The mission comprises **two identical satellites** to halve the time it takes to revisit the same place on Earth's surface and re-measure various direct and indirect variables of the hydropower sector, such as soil moisture, climate monitoring, drought and floods.

Hydro energy has a key role to play in achieving carbon neutrality, and space technologies have the potential to support the sector further. ESA can support European companies eager to work towards this goal across the whole product development cycle: from science-oriented projects (Future EO²⁷) to start-ups via the ESA BIC Network²⁸, or with co-funding via BASS²⁹ or Incubed³⁰.

- | | |
|---------------------------------------|------------------|
| 20. SATELLITE DATA GIVE UNEXPECTED... | 27. FUTURE EO... |
| 21. WATER JADE... | 28. ESA BIC... |
| 22. EOMAP... | 29. BASS... |
| 23. SNOWCAP... | 30. INCUBED... |
| 24. GARIEP DAM COMPARISON... | |
| 25. HYPOS... | |
| 26. MAPPING AND MONITORING... | |



A dramatic, high-contrast photograph of a massive ocean wave curling over, creating a large tunnel-like structure. The water is a deep, dark blue, while the foam and spray are bright white. In the foreground, a faint rainbow is visible, its colors blending into the dark water. The sky is a pale, hazy blue.

Space for renewable energy

**Space commercialisation
for ocean energy**



Space commercialisation for ocean energy

The rise of the ocean energy sector

Ocean energy has a key role to play in the energy transition in countries with coastal areas and island territories. Progress on technological and industrial level can be observed with worldwide funding increasing as governments make bigger commitments to ocean energy as a means of strengthening the security of energy supply and strategic autonomy. While presenting a huge potential the technology overall for ocean energy is still at an early stage of development.

Nevertheless, the potential is also highlighted by International Renewable Energy Agency (IRENA) which indicates that in an energy transition scenario aligned with the 1.5C Paris Agreement target, that ocean energy cumulative capacity of more than 70 GW by 2030 and 350 GW by 2050 could be installed globally¹.

Tidal barrage and stream, wave energy, salinity and temperature gradient are the main sources of ocean energy. Wave energy and tidal stream converters are the most mature and applicable across different geographies. Global total tidal stream saw an increase of 1.7MW of new installations in 2022, accumulating to a total of 41.2MW since 2010. On the other hand, wave energy increased by 165kW in 2022, 24.9MW of cumulative installations since 2010. Additionally, salinity concentration and temperature gradients solutions are also being developed.

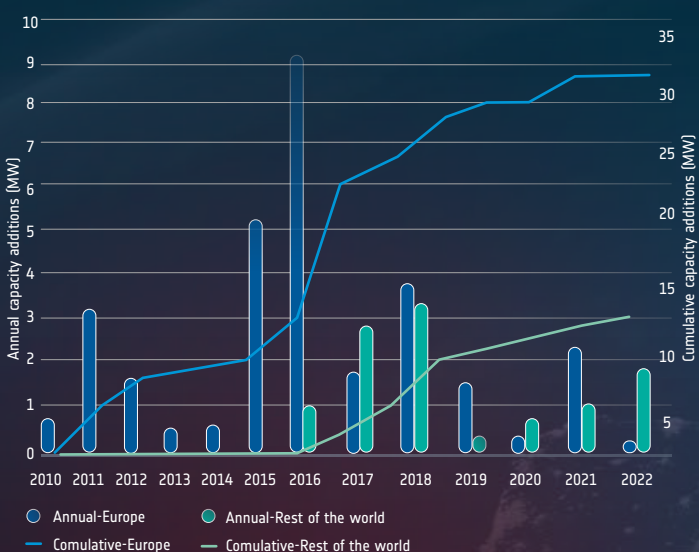


Figure 1: Installed global tidal stream capacity

Global ocean energy potential and deployment, according to IRENA by source: 29 500 TWh (Wave), 1 200 TWh (Tidal stream), 1 650 TWh (Salinity gradient) and 44 000 TWh (Ocean Thermal Energy Conversion - OTEC).

While Europe is leading in cumulative capacity other major economies such as China and the USA are ramping up in annual capacity additions and increasing investments (US\$ 110 million annually boost as of 2022). The UK, France and Canada in particular are offering revenue support through government contracts with Canada having the 2nd biggest project pipeline which will generate 32MW. A comprehensive policy framework including capital grants, feed in tariffs and dedicated deployment sites is a key driver for further growth of this sector².

Small Island Developing States (SIDS) and some Least Developed Countries (LDC) are also expected to become major beneficiaries of the blue economy with ocean technologies helping to address acute energy and water challenges in small-island or remote coastal areas in developing states. Subsequently, also creating socio-economic opportunities such as job creation, strengthening people's livelihoods and improve health outcomes³. This is also echoed by the United Nations Industrial Development Organization (UNIDO) which launched the Global Ocean Energy Alliance (GLOEA) last year and will address the needs of SIDS and LDCs to access ocean energy technology, finance, and expertise.⁴



1. OFFSHORE RENEWABLES...
2. Ocean Energy Europe: Key trends and statistics 2022
3. IRENA Offshore Renewables 2020
4. LAUNCH OF THE GLOBAL OCEAN...



European ocean energy landscape and players

Europe with its 5 sea basins has massive potential for ocean energy and a variety of technologies can harness renewable energy from the sea making it an important source for a clean energy transition.

Europe has held a key competitive advantage in ocean energy throughout 20 years of investment in R&D. The European Union (EU) countries in particular and private sector have invested more than €4 billion over the last ten years in research and pilot projects on ocean energy. Cost reduction will be key for ocean technologies and the EU has set this target for the next decade through the Strategic Energy Technology Plan⁵. This investment has led to a lot of competition in the European market with companies trying to impose their marine turbine or wave energy converter concepts for mass production. The tidal stream sector in that sense seems to be the most mature by launching its first commercial projects benefiting from power purchase agreements. The wave energy is however closely following with testing prototypes to deal with differing European coastal wave conditions⁶.

The EU strategy on offshore renewable Energy (EU offshore strategy) set development targets for ocean energy of 100MW by 2030 and 1GW by 2050. Non-binding agreements were reached within Member States' basins and funding increased by Horizon Europe (78 million euros)⁷. Meanwhile, the United Kingdom (UK) managed to create a market for tidal energy, as its government invested 20M euros to support the deployment

of 40MW of tidal pilot farms – equivalent to 40% of the EU offshore strategy's targets for ocean energy. For its part, the Spanish government invested 200M euros in grant programmes for ocean energy R&D⁸.

In 2022, 67kW of new capacity in tidal streams installations were added and cumulative installations amounted to 30.2MW installed in Europe since 2010. The European tidal stream sector exported 11.9GWh in 2022, led by flagship projects in Scotland including MeyGen, Orbital Marine Power O2 and Magallanes ATIR turbine, and the Tocado's Oosterschelde plant in the Netherlands. Biggest investments for tidal stream projects were Seacurrent⁹ (4.8M euros), Orbital Marine Power¹⁰ (4.5M euros), and Sabella¹¹ (2.5M euros). As of 2023, Nova Innovation will extend its tidal farm with two additional 100 kW turbines, being the largest array in the world.



Nova Innovation Gearless Tidal Turbine

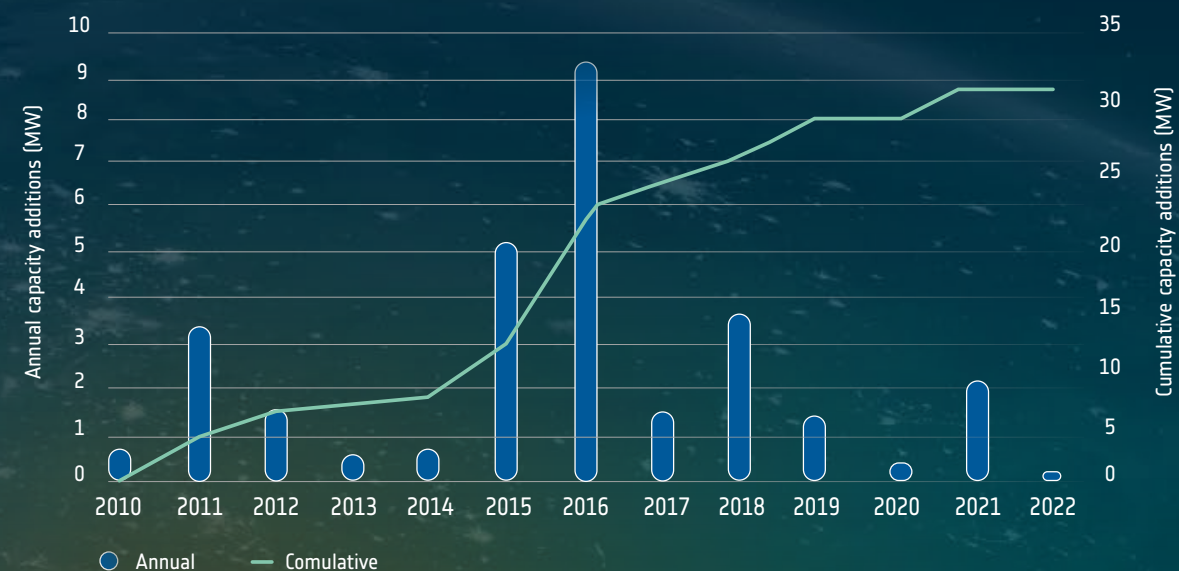


Figure 2: Annual and cumulative tidal stream capacity in Europa

5. OFFSHORE RENEWABLE ENERGY...
6. EuroObserv: Ocean Energy Barometer
7. OFFSHORE RENEWABLE ENERGY...
8. Ocean Energy Europe: key trends and statistics 2022
9. HOME - SEACURRENT...
10. ORBITAL MARINE POWER | LEADERS IN...
11. SABELLA'S TIDAL TURBINES: TIDAL STREAM POWER...



On the other hand, wave energy added 46kW of new capacity in 2022, amounting to a cumulative installation of 12.7MW in Europe since 2010. Funding programmes to foster innovation and boost future developments must continue, as for example the Archimides Waveswing, deployed by Wave Energy Scotland under the EU funded Europe Wave programme. Moreover, three new European ocean energy developments in 2022 were built in Slovenia (30kW), UK (16kW), and Belgium (3.5kW). In Portugal in 2023, CorPower Ocean's flagship project plans to deliver four system wave array of 300kW each and create the biggest grid connected wave farm in the world¹².

Some of the challenges faced by the ocean energy sector are similar to those for offshore wind. Grid connections, supply chain developments and operation and maintenance under harsh weather conditions are to name a few. However, ocean energy is now at a critical stage, moving from prototype to commercialisation where a clear, stable and supportive policy framework will help in attracting further investment so that it can provide cost-effective, low-carbon electricity as well as new jobs and economic growth in Europe¹³.



CorPower Ocean's HiWave-5 Flagship project

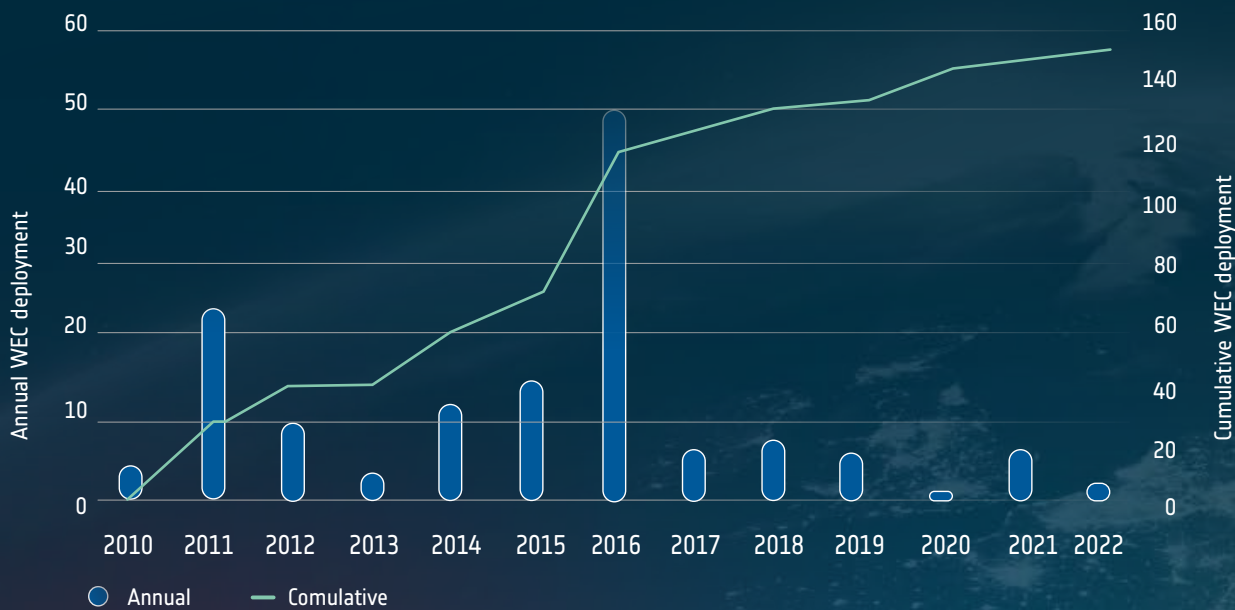


Figure 3: Annual and cumulative wave energy converter (WEC) deployments in Europe

12. Ocean Energy Europe: key trends and statistics 2022
13. Blue Energy – Action needed to deliver on the potential of ocean energy in European Seas and oceans by 2020 and beyond

Ocean energy needs and trends

LOCATION SCOUTING AND CLIMATE RELATED HAZARDS

Successful location scouting is critical to ensure a high production yield. The ocean is a hostile environment, which makes it even more important to monitor related climate hazards and chose locations that minimise the risk of damages to installations while assuring maximisation of ocean energy output. Data is key to make informed decisions on location potential, especially with regards to mapping of historical and forecasted data. Important indicators include ocean current speed and direction, water depth, ocean temperature, ocean salinity, distance to shore, wave height and frequency, and marine life.

BANKABILITY AND EFFICIENCY

Projects need to secure the financing from investors and banks, especially since ocean energy technology readiness is not entirely mature, which can limit its bankability. Resource assessment and planning of the overall economic feasibility of the project need to be assured. Moreover, regulations and permits need to be approved, as not all high potential energy areas can host ocean energy installations due to for example environmental preservation concerns (see next paragraph).

POLICY AND ENVIRONMENTAL IMPACT

The need for data collection for environmental policy monitoring and reporting across the energy value chain is given on all public levels. In spite of the environmental benefits of marine energy in terms of emissions reductions, there are potential negative and positive impacts that developments may have on the marine environment and coastal areas. In order to obtain relevant approvals and permits for installations and operations, environmental impact of commissioning and potentially decommissioning of marine energy plants need to be assessed and carefully monitored. The Blue Technology Barometer measures the degree to which economies are prioritising the protection of ocean health, through sustainable marine activity, blue innovation, and policy implementation¹⁴. Four European countries lead the worldwide ranking, these being: UK, Germany, Denmark and Finland.

SYSTEM PLANNING & TRANSMISSION

One of the challenges of the renewable energy transition remains energy system modelling for policy making including forecasting along mid- and long-term horizons (10-15 years). The increasing dependency on weather access to related databases with accurate past and present information, is fundamental for securing ocean energy supply. There is thus a need to digest raw data and transform them in useable information at planning and

system level. This capability is especially important at national level where countries are looking to tap into emerging offshore energy (wave, tidal, salinity gradient, ocean thermal energy conversion, offshore grid planning and installation), but also at regional level where cooperations are increasingly supporting ocean energy developments.

MAINTENANCE & MONITORING

Ocean environments can be highly erosive and hard to reach, making maintenance very complex, especially in areas with high wave power potential. There is a strong need for regular site monitoring and analysis in order to identify any anomalies and reduce the risk of costly maintenance visits. Weather windows are carefully monitored to send specialised teams, which will also rely on integrated monitoring solutions enabled by reliable and robust navigation and communication services, needed for the harsh and remote locations of the ocean energy power sites. The longevity and successful performance of these is thus highly dependent on adequate maintenance (clean sites, inspect, test, and perform repairs), which in return will play a key role in the overall commercial viability of these sites.

Overall, specific aspects of ocean energy systems, such as spatial planning, logistics and marine operations, environmental protection, integration in the energy system, and overall data transmission are some of the challenges that need to be addressed. Wave forecasts and long-term data are crucial, including sensors (currently often cameras are used) which will also enhance the need for data transfer in these remote areas as well as solutions for installation, maintenance and monitoring activities.



14. THE BLUE TECHNOLOGY BAROMETER 2022/23...

Space sector added value

In spite of the significant potential, the ocean energy sector is currently emerging and will depend on overcoming key challenges such as the technology readiness & maturity, bankability, efficiency & safety in operations and maintenance and its environmental sustainability.

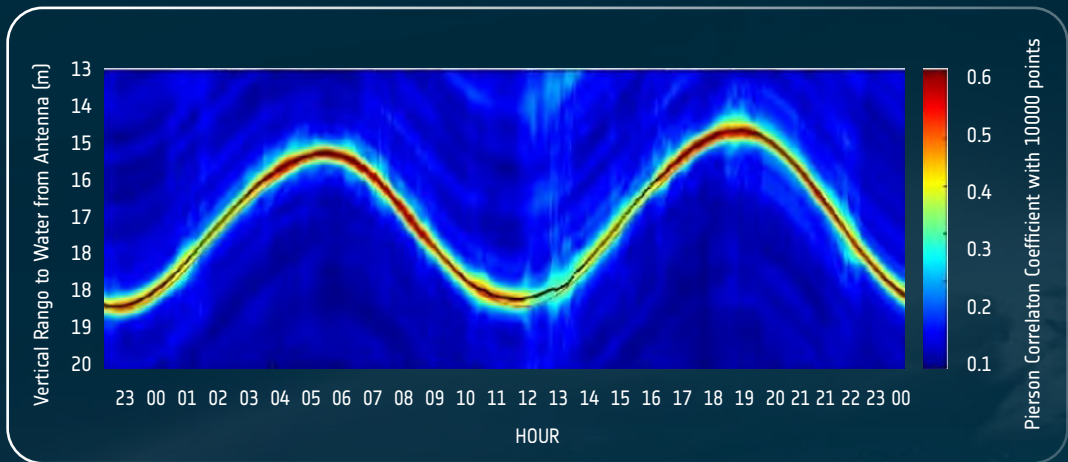
Space-based applications and technologies can play an important role to some of those challenges. For example, it can provide hydrodynamic models data, which are useful for revenues forecast, monitor the environmental impact and increase survivability of marine energy installations.

The Business Applications – Space Solutions (BASS) programme is one of the entry points to ESA which supports European companies including start-ups and SMEs to develop commercially sustainable services using space technologies and data. Considering the importance of the ocean energy sector and the European Marine Energy Landscape, the BASS programme launched in 2020 an Open Call related to Marine Energy.

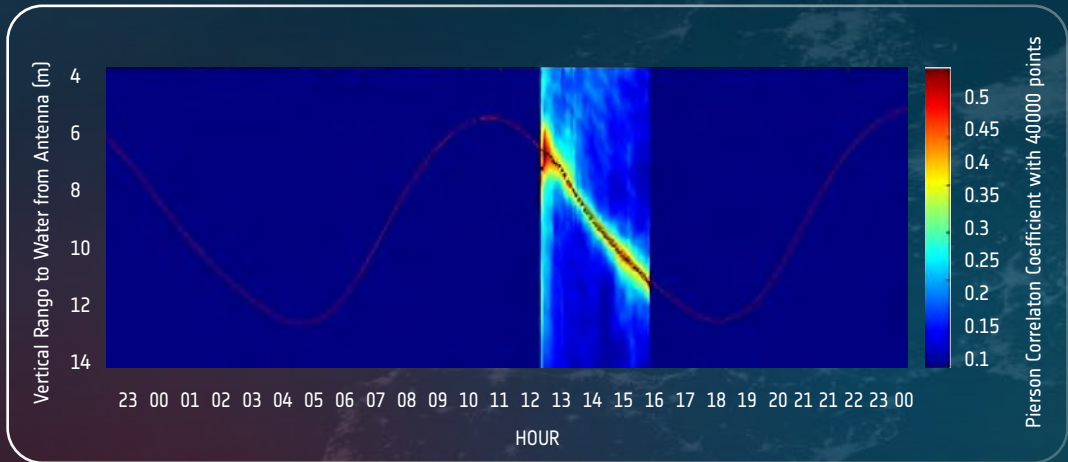
Under the flag of ESA's Earth Observation [Atlantic Regional Initiative](#), the National Oceanography Centre (NOC) of the UK, is working with the European Marine Energy Centre (EMEC), one of the world leading Marine Renewable Energy Test Centres, to improve sea state characterisation in high energy environments by using GNSS-IR technology. The European Space Agency also offers multiple EO datasets through its Third Party Mission programme which can pave the way towards the development of new ocean energy solutions.

Moreover, through the ESA's Business Incubation Centres (BIC), new ocean startups are being supported. Oceanenergy AG Technologies for example is building technology components to improve Wave Energy Conversion (WEC) devices so that it can bring the levelized cost of energy (LCOE) of tidal energy to the windows of more cost competitive renewable sources such as wind and solar.

Siglo RNLI Station GPS Reflectometry Water Levels: 02 Aug 2019



Alfred Dock Test: Ublox 9 GNSS Reflectometry Water Levels: 09 Aug 2021



GNSS Interferometric Reflectometry for water level detection

Also Marine Energy Space Control (MESPA) (initiated from the BASS Marine Energy Call) resulted to the establishment of a new start-up company (MESPA Srl.) incubated at the BIC. They are aiming to use earth observation and AI with surface sensors to provide analysis of met-ocean characteristics which can be suitable for bankability estimations, advanced design activities, monitoring and control of operations for new offshore energy projects.



Several of the previously exposed needs can be covered thanks to data coming from earth observation, communication, and navigation satellites.

Firstly, it can address the environmental concerns of new installations (e.g. pollution at sea, marine habitats, coastal ecosystem, detection of harmful liquid spills), as satellites are able to monitor key variables in the field of environmental impact assessment and pollution.

Secondly, system planning and forecasting can be vastly supported through space. The role of weather and other satellite-derived data is already highlighted by Copernicus and the European Centre for Medium-Range Weather Forecasts activities. The capability of planning and forecasting will allow a better balance and efficient use of the energy between countries, networks and regions. Satellites will be able to analyse ocean characteristics to optimise the selection of power stations and assessment of their power potential.

During the construction phase, met-ocean forecasts, and climatology for hazard prevention and mitigation on offshore infrastructure, will help reduce and anticipate delays. Also, autonomous vessels and communication between offshore and shore including M2M (for process automation and end-to-end business processes) and voice and data, may help to improve logistics efficiency during the construction and maintenance phases.

Navigation and communication systems allow remote control and access to large data sources for predictive maintenance and energy efficiency, detecting and quantifying vessel traffic management and coordination for transport and fishery. Navigation satellites can optimise transport routes to enhance energy efficiency, enable autonomous water vehicles, while providing weather and sea forecasts for routing of ships and planes.

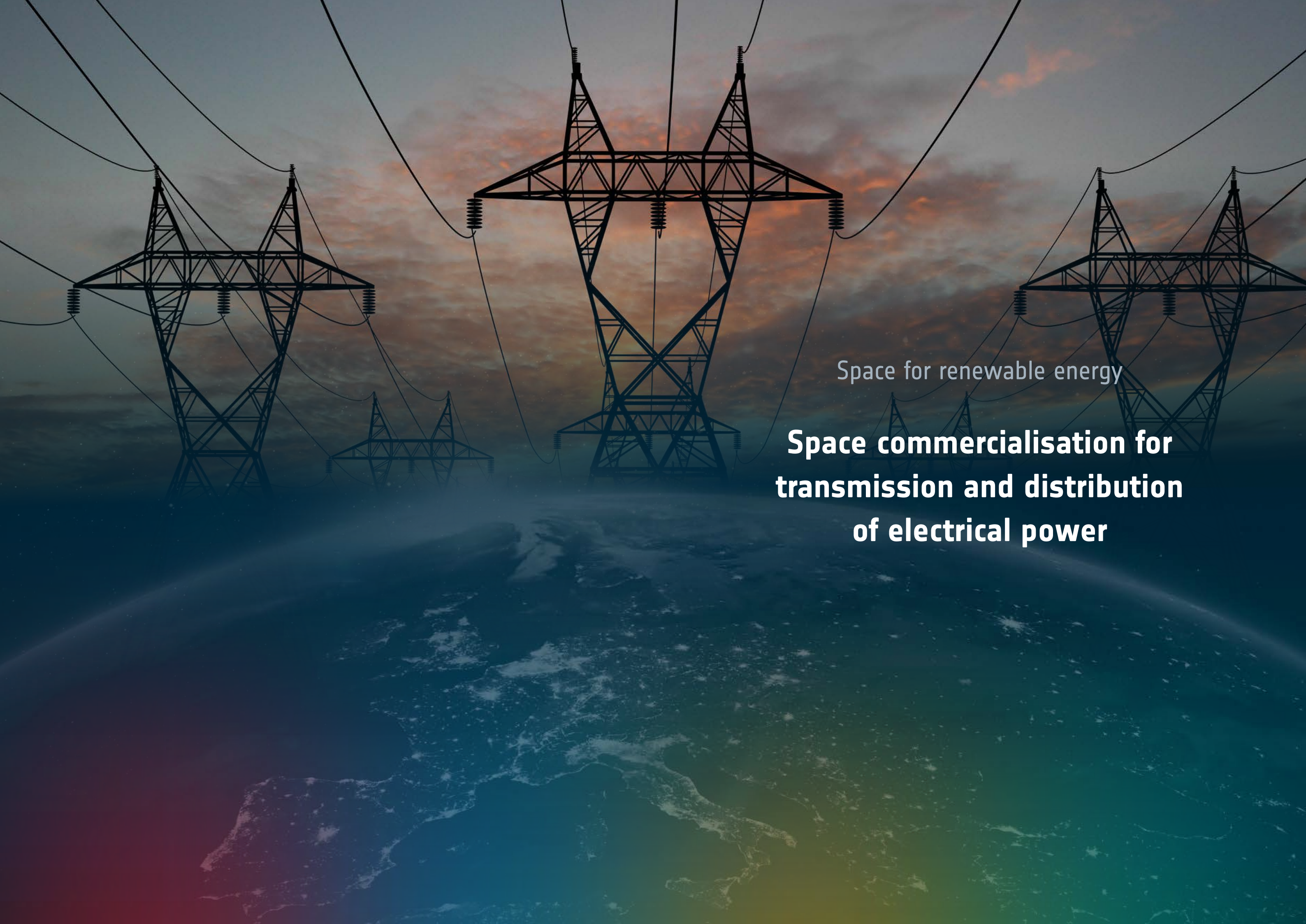
All the Earth Observation related use cases are possible thanks to Copernicus Marine Environment Monitoring Service (CMEMS) and sentinel missions. CMEMS uses synthetic aperture radar (SAR) data to provide information on marine surface wind speed and direction, allowing offshore wind energy potential estimates to be calculated. The sentinels provide continuous data on the behaviour, use, and health of the oceans. Particularly, sentinel-1 provides an all-weather, day-and-night radar imaging capability. And Sentinel-3 provides a multi-instrument capability to support parameters as Ocean Colour (OC), Sea Surface Height (SSH) and Sea Surface Temperature (SST)¹⁵.

There are no alternatives to satellites supply forecasts based on current and historical data. The sector is in need for solutions on European, National, and regional level, which creates a commercial opportunity to strategically place data coming from satellites. Overall, the added value of space in the field of ocean energy is immense and in line with policy needs in Europe and worldwide.



ESA's SMOS mission observes ocean salinity



The image is a composite. The upper portion features a series of high-voltage electrical pylons and power lines, silhouetted against a dramatic sky with orange and pink clouds from a sunset or sunrise. The lower portion of the image shows a view of Earth from space, with swirling white clouds and a dark blue ocean. A rainbow-like light gradient is visible across the bottom of the image, transitioning from purple on the left to green and yellow on the right.

Space for renewable energy

**Space commercialisation for
transmission and distribution
of electrical power**

Space commercialisation for transmission and distribution of electrical power

Introduction to the Transmission and Distribution (T&D) market

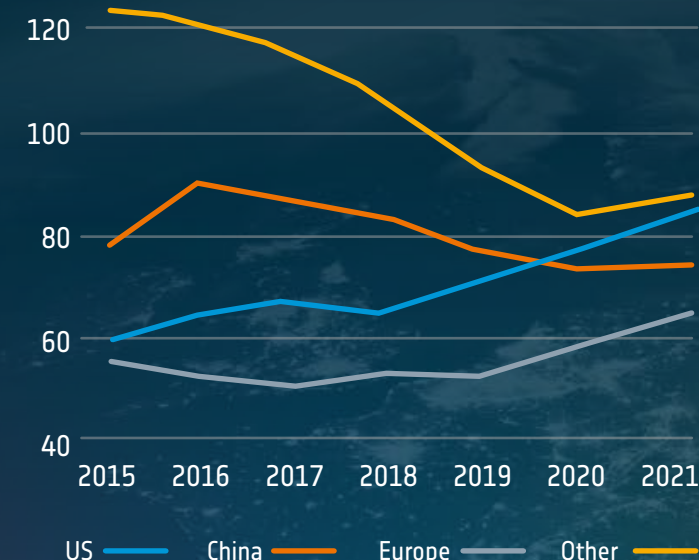
Power transmission lines, which transport electricity from power plants at high voltage over long distances, are over 7 million kilometres long globally. They are connected to shorter distribution lines, with lower voltage electricity, that transport electricity to customers. These cover over 72 million kilometres in total. Together these lines make up the global electric power T&D equipment market, which is **valued at US\$151.99bn in 2021** and is expected to expand at a **Compound Annual Growth Rate (CAGR) of 6.4% from 2023 to 2030¹**. This growth is mainly due to increasing demand for electricity, particularly in remote parts of the world, where populations do not yet have reliable access to electricity.

Asia Pacific accounts for most of the global T&D revenue market share, with 53% in 2022². It is led by China with an average investment share of 27% between 2015 and 2021, and plans to invest primarily in ultra-high-voltage projects and grid digitalisation³. It is followed by the **United States (US)** which had a stronger investment growth rate in the last years.

Calculated by grid length, the largest transmission system operators (TSOs) in 2021 were: the State Grid Corporation of China (China), China Southern Power Grid Co Ltd (China) and Xcel Energy Inc (US)⁴. The largest distribution system operators (DSOs) in line length were MRSK Yug PAO (Russia), Enel SpA (Italy) and Enedis SA (France)⁵.

The Paris Agreement set an objective of **reaching carbon neutrality by 2050**. To achieve this objective, renewable energy sources are expected to increase exponentially, but their integration requires a drastic transformation of the T&D network.

Firstly, **renewable power generation** fluctuates strongly based on weather conditions. Consequently, **major investment in smart grids**, as in networks leveraging advanced digital technologies to serve multiple varying electricity generation sources and demand, are planned. Furthermore, they offer a robust solution to cater for the power demand of the rapidly rising number of electric vehicles. Secondly, to capture optimal weather conditions and to meet large space requirements, they are located much further away from customers. This results in **longer grid distances** for which high-voltage direct current (HVDC) lines must be used to minimise energy loss during transport. These numerous new plants scattered over long distances are **decentralising the market**.



Investment spending on electricity, 2015-2021 (in US\$bn)³

1. GLOBAL POWER TRANSMISSION AND DISTRIBUTION...
2. ELECTRIC POWER TRANSMISSION AND DISTRIBUTION...
3. SMART GRIDS...
4. TOP 10 TRANSMISSION SYSTEM OPERATORS...
5. TOP 10 TRANSMISSION SYSTEM OPERATORS...



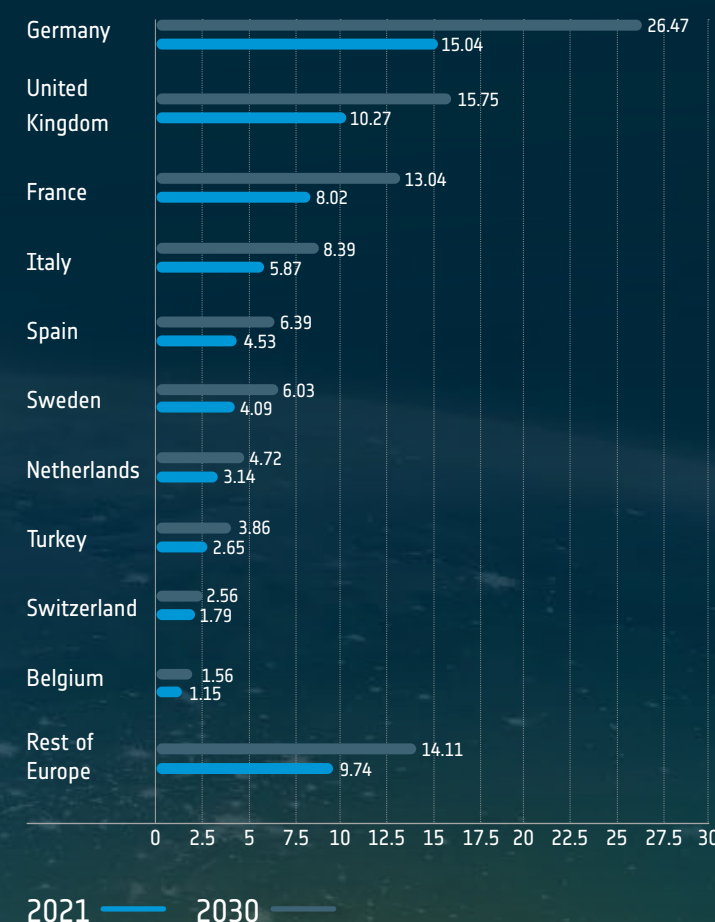
By 2030, investments in electricity grids should almost **double** in order to strengthen existing infrastructure and construct new lines. However, these new construction projects take a very long time, and face social challenges such as local opposition to overhead lines and lengthy permit acquisition processes for cross-jurisdiction.

In developing economies specifically, this investment is **expected to triple⁶**. Their electricity demand is rising due to population and economic growth, while their T&D systems are mostly inadequate or inefficient. To cater for their needs in rural and remote areas, **microgrids are increasingly being considered**.

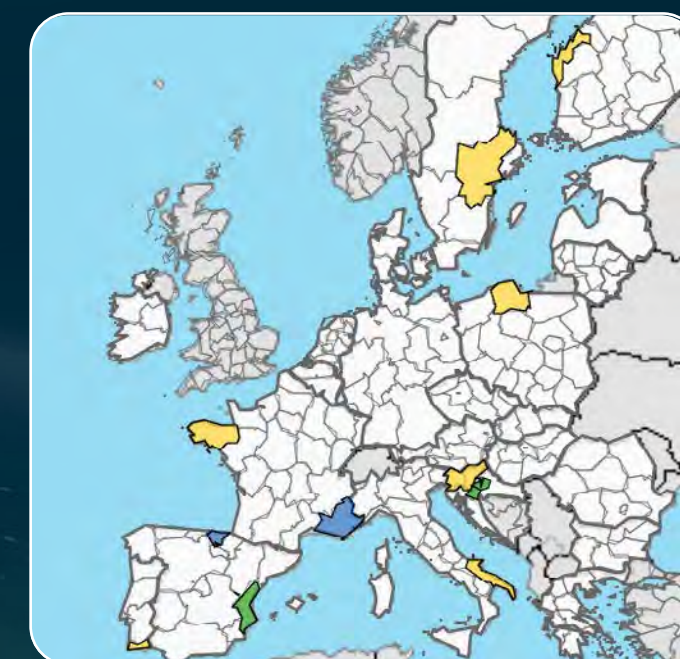
European T&D market overview

Europe invests **yearly more than €40bn** in its power grids, and much more investment is forecast in the coming years⁷. The market is expected to grow at a **CAGR of 6.55% between 2023 and 2030⁸**. This growth is driven by industrial growth, rising electricity demand particularly in renewables and the refurbishment of outdated infrastructure⁹.

In addition to the global T&D market trends, the EU is shifting its focus towards greater collaboration among regions and countries within the EU. On one hand, interregional partnerships are being promoted, led by the European Commission through the Smart Specialisation Platform on Energy (S3PEnergy) initiative¹¹. The objective is to combine strengths and research capabilities, overcome market fragmentation and encourage co-investments. Under S3PEnergy, ten regions across nine countries are currently collaborating on smart grid development projects¹².



Electricity transmission and distribution revenue in Europe 2021-2030, by country. In 2021, Europe's largest players in terms of T&D revenue were **Germany, the UK, France and Italy**. While all are expected to maintain their leading position, **Germany is forecast to show the most significant growth by 2030¹⁰**.



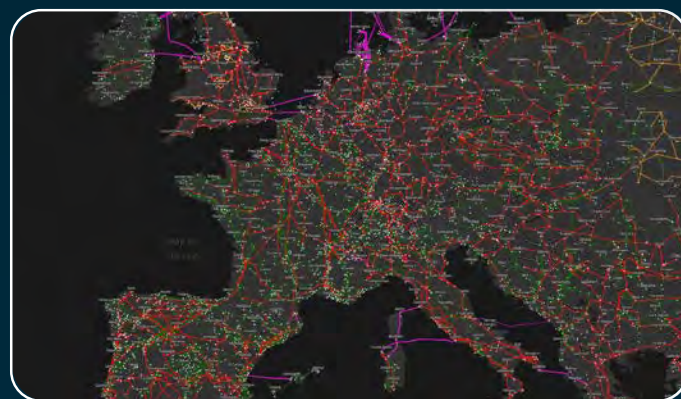
- Interested regions
- Participating regions
- Leading regions

Regions involved in the S3PEnergy smart grids partnership¹¹

6. SMART GRIDS...
7. WITHOUT GRID ENHANCEMENTS EUROPE...
8. GLOBAL POWER TRANSMISSION AND DISTRIBUTION...
9. GLOBAL POWER TRANSMISSION AND DISTRIBUTION...
10. ELECTRICITY TRANSMISSION AND DISTRIBUTION MARKET...
11. SMART SPECIALISATION PLATFORM. ENERGY...
12. SMART SPECIALISATION PLATFORM. SMART GRIDS...



On the other hand, the EU is striving to fuel **more internationalisation by constructing** cross-country electricity interconnections. These are provided by TSOs, they cover very long distances using HVDC or ultra-HVDC, above 500hV and 800kV respectively. The underlying objectives are to increase electricity supply security, lower risks of blackouts, and to manage fluctuations of renewable sources. The EU has set a target of at least 15% of interconnections by 2030¹³. However, the politics behind it are complicated, thus slowing implementation. Furthermore, electricity loss on the network for European countries varies between 4 and 17%¹⁴. As mentioned previously, the longer the distances, the greater the losses, thereby exacerbating this challenge.



ENTSO-E TSO Interconnected Network System Grid map¹⁵

T&D Needs: Harnessing the Potential of Space Technologies

Ageing T&D assets must be modernised to remain efficient and to cater for new market needs. This offers new application potential for space-based solutions in Europe and all over the world.

MONITORING AND MAINTENANCE OF THE GRID INFRASTRUCTURE

The **number of power lines is projected to increase** to meet the rising customer needs. In parallel, supergrid development and renewables will increase the deployment rate of **very long-distance grids**. This will further complicate grid monitoring and maintenance, with the result that new automated ways must be sought to perform these tasks at low cost.

Environmental and geo-hazard

Grid damage caused by weather events is increasing due to climate change. Synthetic Aperture Radar (SAR) satellite data can be used to **monitor weather events and geo-hazards** (such as snow, ice load and wind). Satellites are being used to monitor weather conditions and Earth observation (EO) imagery can be used to monitor the infrastructure directly. **Vegetation management risk** leads to electricity outages or wildfires, and represents one of the largest operating expenses for TSOs. New solutions are needed to replace the current ways of doing things which are labour intensive and costly, operated through helicopters, drones and crews. SAR and optical EO can be used to **monitor the vegetation** around the grids by capturing information such as tree species, high estimation or positioning relative to the power line so as to develop prediction models.

Structural integrity

Other space technologies such as the Differential Global Navigation Satellite System (DGNSS) can be used to **monitor the structural integrity of critical infrastructure**. Furthermore, satellites can provide time stamping of grid data to monitor the power lines or to perform **conductivity and hot spot measurements**.



- 13. ELECTRICITY INTERCONNECTION TARGETS...
- 14. T&D EUROPE...
- 15. ENTSO-E TRANSMISSION SYSTEM MAP...



Human-generated threats

Risks to the integrity of the power lines are mainly through cyber-attacks but also physical attacks. Infrastructures are vast and therefore are both difficult to monitor and vulnerable. In certain regions of the world the number of attacks has been increasing rapidly; for instance in the US, physical attacks increased by 77% in 2022.

VIRTUAL POWER PLANTS (VPP), SMART AND MICRO-GRID SOLUTIONS TO BALANCE SUPPLY AND DEMAND

The European T&D market requires new digital solutions to balance electricity generation and consumption using real-time data, in turn helping the grid become more stable. The prime solution to this challenge is smart grids, enabled by VPPs, which are cloud computing-based technologies that aggregate various power sources, storage facilities and consumption to coordinate the whole network.

Accurate and timely forecasting of electricity generation of renewables and consumption is necessary for smart grids and VPPs to make optimal planning of electricity supply while preventing outages. Satellite-based sensors can be used to forecast energy generation based on weather conditions. In parallel, real time high-resolution EO imagery which covers large areas can be used to forecast electrical consumption.

Some space-related initiatives in Europe

There is strong potential for space technologies to help provide electricity efficiently and securely at a low cost. In 2018, ESA created a collaboration to support the use of satellite applications for European power grids, namely together with the European Network of Transmission System Operators (ENTSO-E), the European Distribution System Operators Association (EDSO) and the Enel Group. A special focus was placed on smart grids, grid maintenance and technology enablers such as satellite for 5G or the IoT¹⁶. In parallel, ESA's programmes are supporting the development of multiple initiatives as mentioned below.



Space communication technologies provide a reliable means for **remote control and communication**. Smart grids require satellite enabled bi-directional info flow and GNSS enables time synchronisation in micro/nanosecond precision for phasor measurement units which measure the voltage and digital fraud recorder. Finally, satellite communication enables the development of Internet of Things (IoT) services sensors.

Lastly, microgrid development must be pursued to offer a simpler and sustainable solution to remote and rural areas for populations lacking a secure electricity network, as well as for more developed regions. Indeed, they offer numerous benefits such as lower costs, grid independence which enhances resilience to grid failures and reduces congestion, risk diversification, and provides electricity storage.



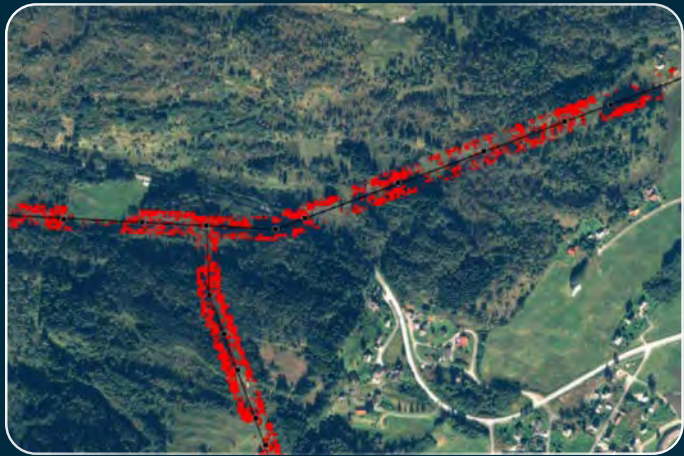
MONITORING T&D INFRASTRUCTURES

ESA's EO programme as part of its "expand demand" initiative has worked in close collaboration with the company Science and Technology (S&T) to develop the virtual platform Corridor and Asset Monitoring using Earth observation (CAMEO)¹⁷. The overarching goal was to create a platform which grouped a wide range of EO services for companies and agencies managing pipeline and energy transmission corridors. This 2-year initiative which closed in September 2022 highlighted that the need for one central marketplace for such EO services wasn't there yet. However, through workshops and discussions across actors and customers, the **CAMEO has successfully demonstrated the added value of EO data for asset monitoring** in the energy transportation industry which includes electricity grids, as well as oil and gas pipelines. It mainly focused on 3 field of EO-application: structural integrity analysis; environmental and geo-hazards and third-party human interference.

- 16. SPACE-BASED SERVICES FOR DISTRIBUTED ENERGY...
- 17. CORRIDOR AND ASSET MONITORING...



The first, **structural integrity analysis** includes surface deformation and leak occurrence. To capture information relative to this, ESA's Sentinel 1 SAR imagery data can be exploited. The second field covers **environmental and geo-hazards**, under which EO research has extensively focused on flooding, landslides and vegetation change. Flood hazard monitoring can be performed by Sentinel-1 SAR EO data, which is particularly helpful compared to optical data, as radar measurements can visualise through clouds and at night. Vegetation monitoring, namely through Sentinel-2 measurements, has been one of the principal areas of focus of the ESA BASS-supported initiatives GRIDEYES contracted by StormGeo¹⁸. ESA EO observations coupled with artificial intelligence can go as far as identifying tree species and locations relative to the grid to predict their growth and long-term threat.



GridEyeS AI vegetation monitoring¹⁹

Both vegetation encroachment and structural defects for predictive maintenance are explored by GeoAerospace. With the support of ESA, it is developing 3DE, a Platform-as-a-Service (PaaS) solution targeted at the energy sector. A top-down approach is used, leveraging machine learning technics that combine regional scale very high-resolution satellite data, in tandem with localised high-resolution optical and LiDAR data (aircraft and drones). Currently, the company is engaged in a long-term commercial contract with a national utility company providing asset inspection services, during which it aims to continue developing 3DE.

Lastly, **threat assessments of third-party human interference**, can be monitored through Sentinel-1 EO, but so far efforts have mainly focused on buildings and objects close to power lines rather than deliberate human attacks.

In recent years, ESA BIC and BASS (Business Application and Space Solution programme within ESA) have supported several start-ups to develop solutions that cater to all these three fields at once. SatNetMonitor contracted by Headpower and Terramonitor and funded by ESA as well as nine European TSOs and five DSOs, offers a comprehensive solution²⁰. It collects EO data which it combines with a machine learning tool to create automatic alerts and risk maps. In addition, the platform enables the user to monitor task status and make work orders, invoicing and documentation. Some other start-ups supported by ESA BICs use satellite communication to develop other monitoring technics. **Drone monitoring** is being investigated namely by SKYQRAFT²¹, while SENTRISENSE leverage **IoT sensors installed on-site**²².

Beyond infrastructure monitoring, some initiatives aim to **serve energy networks companies, including T&D, across multiple stages of their lifecycle**. Gmatics' ENTEL project, currently in its demonstration phase under ESA BASS, strives to cater for three stages²³. Firstly, to help T&D companies select optimal corridors to plan new lines using a geospatial database complemented by Sentinel satellite imagery to track changes in land cover and land use. Secondly, using very high-resolution satellite imagery, it will monitor construction progress to deliver progress reports, and last, ENTEL's solution will detect the risk of damage from human activities through multi-spectral and radar satellite imaging.

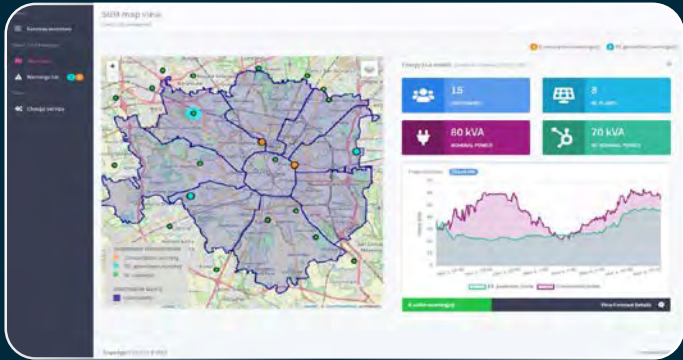
FORECASTING GENERATION AND CONSUMPTION TO IMPROVE SM AND VPPS

On the one hand, major progress is being achieved in **renewable power generation forecasting** using satellite EO technologies as explored in the previously published ESA report on the solar, hydro and wind energy²⁴ markets. On the other hand, **consumption forecasts** are needed to balance supply and demand but applications for satellite in this field are still scarce. Initiatives such as "Greenlytics", supported by ESA BIC Sweden, are striving to do so by leveraging advanced machine learning methods that combine satellite data with weather data from prediction models (e.g. temperature or cloud coverage), as well as ground measurement and behaviour trends (e.g. weekend or holidays)²⁵.

18. GRIDEYES...
19. GRIDEYES. OBJECTIVES OF THE SERVICE...
20. SATNETMONITOR...
21. MAXIMIZE GRID UPTIME WITH DATA...
22. POWERING UP A GREENER FUTURE...
23. ENTEL...
24. MARKET TRENDS...
25. WIND POWER FORECASTS...



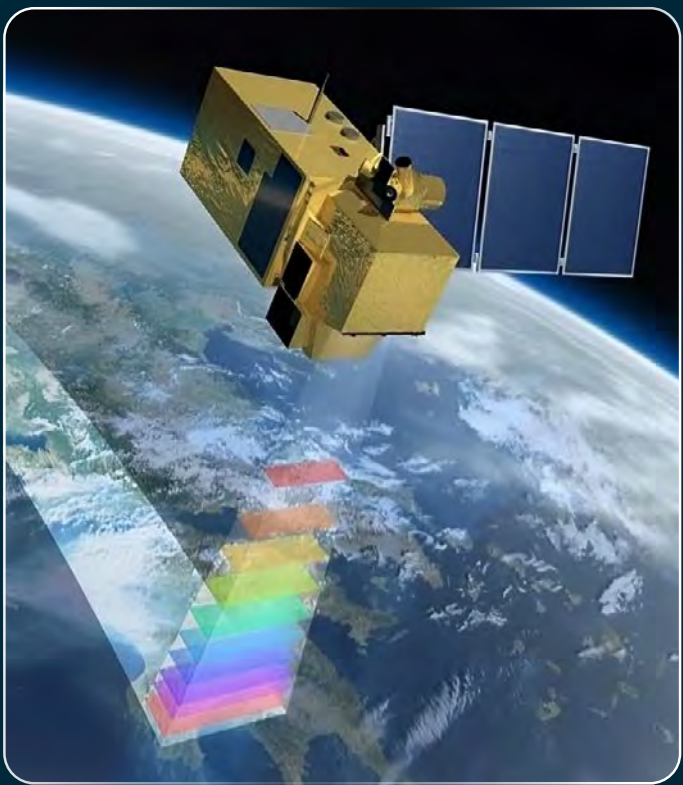
SP4GO, supported by ESA BASS contracted by Flysight and I-EM, offers a full solution for both the aforementioned areas of development: grid monitoring and smart **grid optimisation through generation and consumption forecasting**²⁶. It combines EO from Sentinel-2, grid and weather data, with GNSS data to georeference this metadata. Simultaneously, the platform offers an interactive map displaying consumption and generation warnings based on its consumption estimations.



SP4GO interactive map²⁷

A similar, highly advanced offering is proposed by the company LiveEO, which serves electric grids among other industries to manage vegetation and storm response, ground deformation, and third-party activity through EO²⁸.

Finally, satellites can be used in the context of microgrids as exemplified by MOWGLI, an initiative supported by ESA BASS. It uses EO from Sentinel-2 to plan microgrids based on consumption needs, local source availability and rural area development²⁹. It also uses satellite navigation and communication to complement solutions where local connectivity is not reliable or available, and geolocate mobile-phone users to understand behaviours and the needs of the community.

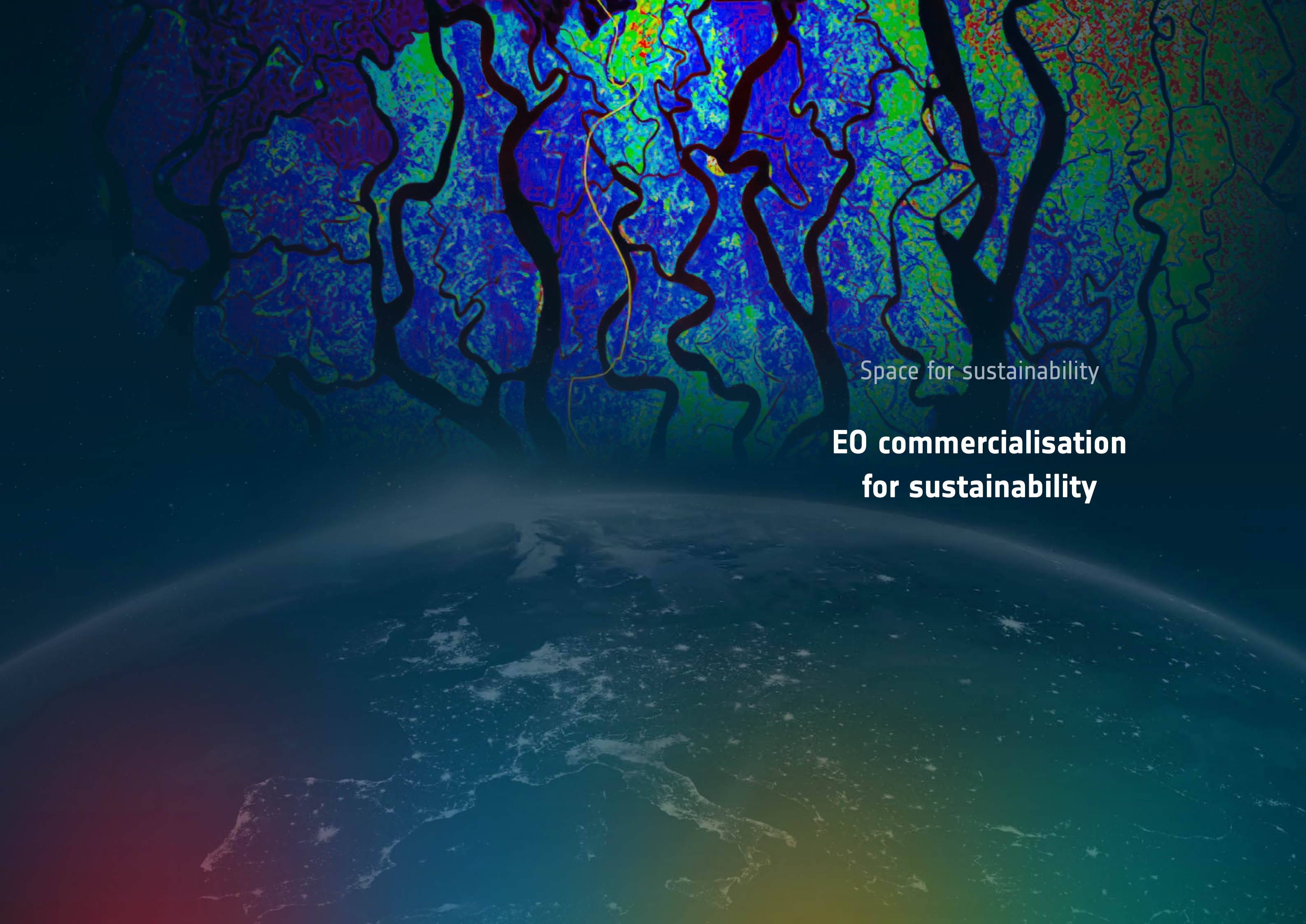


ESA Sentinel 2

Electricity T&D is a crucial element in the energy transition. It is not only a growing market due to the creation of new lines, but also because of emerging market needs such as balancing the grid's fluctuating demand and supply, providing bi-directional communication and electricity exchange, and grid level energy storage options. ESA can support European companies eager to work towards this goal across the whole product development cycle: from science-oriented projects (Future EO³⁰) to start-ups via the ESA BIC Network³¹, or with co-funding via BASS³² or Incubed³³.

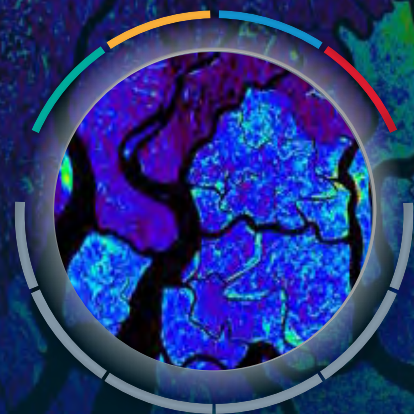
26. SP4GO...
27. SP4GO: SPACE-BASED SERVICES FOR SMART...
28. UNLOCK THE POTENTIAL OF EARTH OBSERVATION...
29. MOWGLI...
30. FUTUREEO...
31. ESA BUSINESS INCUBATION CENTRES...
32. YOUR BUSINESSPOWERED BY SPACE...
33. INCUBED IS AN ESA PROGRAMME...





Space for sustainability

**E0 commercialisation
for sustainability**



EO commercialisation for sustainability

Environmental monitoring: a key action in the fight for sustainability and resilience

Global leaders in business, government and civil society are becoming increasingly aware of the environmental and economic impact of climate change and biodiversity loss on their activities. This was clearly highlighted by the World Economic Forum's Global Risks Report 2022¹ which found that five out of the ten most severe risks perceived by those leaders for the next ten years had their origins in the wider environmental crisis.



Environmental Societal Economic Geopolitical

Most severe risks perceived for the next ten years as identified by the World Economic Forum's Global Risks Report 2022

Moreover, new regulations, such as the EU regulation on deforestation-free products, are placing increasing demands on companies in certain areas to assess their environmental impact. This regulation, combined with the impact of COP26 and the new requirement to report scope 3 emissions, has led many companies to engage in deforestation risk analysis.

WHAT ARE SCOPE 3 EMISSIONS?

The most widely used international accounting tool for greenhouse gas (GHG) emissions, the GHG Protocol², divides GHG emissions into three categories referred to as "scopes":

- **Scope 1** covers direct emissions from owned or controlled sources.
- **Scope 2** covers indirect emissions from the generation of purchased electricity, steam, heating and cooling.
- **Scope 3** includes all other indirect emissions that occur in a company's value chain.

Institutions and companies are therefore now faced with a powerful incentive to analyse and assess the impact of their activities, both to respond to increasingly demanding governmental regulations and also to shift voluntarily towards sustainability and resilience³. To integrate environmental considerations in their decision-making processes, they need reliable, up-to-date information: this is where support from environmental monitoring techniques and tools comes in.

1. Global Risks Report 2022 | World Economic Forum (weforum.org)
2. Greenhouse Gas Protocol | (ghgprotocol.org)
3. Environmental Monitoring | UNECE



Increasing democratisation of Earth observation for environmental monitoring

Thanks to remote-sensing satellites, space enables scientists, decision makers, solution providers and the general public to access a wide range of information about Earth (including physical, chemical and biological data, etc.) that is key to studying and protecting our environment. With the ever-growing range of satellite systems with refined capacities⁴ (heightened spatial resolution, bigger

scene sizes, increasing revisit times) and the development of open access data⁵, Earth observation-based solutions are now being applied to a variety of environmental monitoring use cases⁶: agriculture, sea and coasts, forests, land use, water resources, environmental disasters, air quality and illegal environmental activities.

Earth observation for environmental monitoring use cases

AGRICULTURE MONITORING

Measurement of crop production and tracking of crop condition to improve food security and optimize fertilizer use.

SEA AND COASTAL MONITORING

Mapping of living marine resources and ecosystems, study of shoreline changes, analysis of water quality and ocean salinity, etc.

FOREST MONITORING

Mapping of current and historical forestal cover, management of forest activity and wildlife.

LAND USE MONITORING

Analysis of land cover change, urbanisation and its negative environmental impacts (soil erosion, habitat and biodiversity loss, etc.).

WATER RESOURCE MONITORING

Assessment of water bodies and management of water resource-related activities.

ENVIRONMENTAL DISASTER MONITORING

Identification of factors and effects of various hazards (coastal, meteorological, fire-related, etc.).

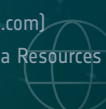
AIR QUALITY MONITORING

Monitoring of air quality and analysis of the effect of human activities on air pollution.

ILLEGAL ENVIRONMENTAL ACTIVITIES MONITORING

Detection of illegal environmental activities such as unauthorised dumping of trash in nature or fishing in protected maritime areas.

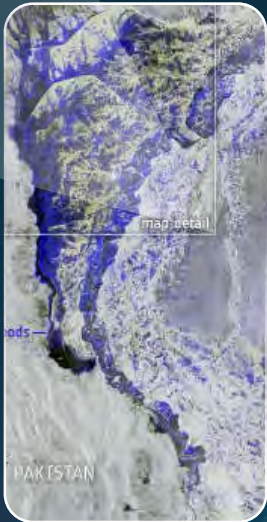
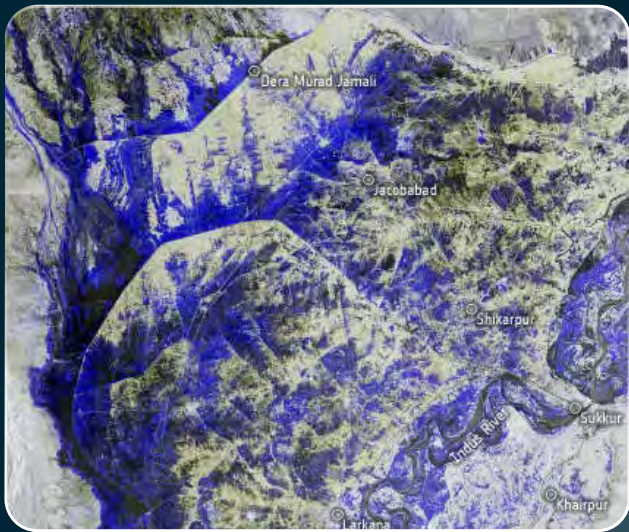
4. Capturing value from earth observation analytics | Arthur D. Little (adlittle.com)
5. Satellite platforms: free and open data for environmental monitoring »Gaia Resources
6. Earth Observation for Policy (rff.org)



According to the European Union Agency for the Space Programme, the environmental monitoring segment accounts for approximately 5% of the global Earth observation market, whose total revenue is roughly €2.8bn. By adding in the market shares of the agriculture, climate services, biodiversity, ecosystems and natural capital, forestry, fisheries and aquaculture segments, environment-related use cases represent almost 30% of the global Earth observation market.

Awareness of the added value Earth observation can bring for environmental monitoring purposes has even reached the general public: satellite images have become commonplace in news reports on climate change and related disasters such as the devastating floods that hit Pakistan in 2022⁷.

➔ Earth observation-based products and services are therefore fully recognised as innovative and reliable environmental management solutions.



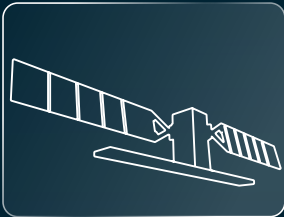
An image of the floods in Pakistan taken by Copernicus satellite Sentinel-1 on 30 July 2022

7. Pakistan flood created a 100km-wide lake, satellite images show | CNN

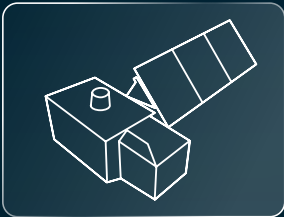
Earth observation for environmental monitoring: commercial companies complementing public open source data

The acquisition, transmission and analysis of environmental data from satellites have led to a growing market, often fuelled by the R&D activities carried out by space agencies. As a result, opportunities have opened up for private companies to offer products and services that use this data to support informed decision-making. With environmental protection at its core⁸, the European Union's flagship programme Copernicus⁹, for instance, provides a vast amount of unified data that currently feeds into a wide range of private platforms' thematic information

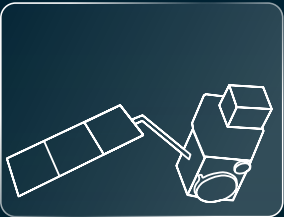
services that benefit our planet and grow our economy. The programme furnishes data that helps us to monitor a myriad of environmental parameters on land, in oceans and in the atmosphere. Furthermore, under the European Space Agency (ESA) Third Party Missions Programme¹⁰ (TPM), datasets from Earth observation missions that are not ESA-owned or -operated are distributed to scientific users under specific agreements. Currently covering over 60 instruments on more than 50 missions, ESA's TPM has been operating for over 45 years.



sentinel-1
Carries a radar to provide all-weather, day and night imagery to monitor oceans ice and land, and to aid emergency response.



sentinel-2
Carries a high resolution multispectral imager to monitor land and vegetation cover.



sentinel-3
Carries an instrument package including a radar altimeter, an infrared radiometer and an imaging spectrometer, to monitoring oceans and land.



sentinel-5p
Carries a spectrometer, primarily to monitor global atmospheric pollution.



sentinel-4
Is a spectrometer carried on the Meteosat Third Generation Sounder satellites. It is dedicated to monitoring air quality over Europe.



sentinel-5
Is a spectrometer carried on the MetOp Second Generation satellites. It is dedicated global air quality.



sentinel-6
Carries a radar altimeter to measure global sea-surface height for operational oceanography and for climate studies.

Presentation of the Sentinels satellites (source: "The Ever Growing Use of Copernicus across Europe's Regions")

8. Accueil | Copernicus
9. OBSERVER: The Copernicus Contribution to the latest Intergovernmental Panel on Climate Change report | Copernicus
10. Third Party Missions - Earth Online [esa.int]

Data is also gathered by private companies such as Airbus¹¹, which in so doing has achieved an international presence, while an increasing number of European companies are developing private constellations that make it possible to acquire data at lower costs. Some of these have been actively seeking new capital to grow globally and position themselves on innovative environmental monitoring solutions: world-leading SAR data provider ICEYE, for example, announced in 2022 the closing of a \$136m Series D funding round that it is currently leveraging to grow its natural catastrophe solutions.

However, the added value of new entrants and the key role of European players are especially important when it comes to turning satellite data into insights for providing value-added services close to the end user. New entrants can now take advantage of the open data infrastructure (notably through Copernicus), which has eliminated the price point issue – previously the greatest barrier to entry for downstream companies. In use cases where market, regulations and science converge, companies are now able to build successful business models. A prime example of one of these use cases today is deforestation, with companies such as Satelligence moving towards a position where they can finance their development through commercial contracts and rely less on grants. Satelligence's value proposition is to connect companies' supply chains to what is happening in the environment through the analysis of open satellite data from NASA and the Copernicus programme. After a successful development activity co-

funded by the ESA InCubed programme, which enabled the company to complete early testing of its solution, Satelligence has launched Deepview. With its capacity to map the relationships between producers, traders and goods manufacturers to identify deforestation risk throughout the value chain, Deepview directly addresses a key issue for many firms following the EU regulation on deforestation-free products and the requirement to report scope 3 emissions. Other downstream service companies, known as one-stop-shops, are also entering into partnerships with private image-providers to create satellite imagery marketplaces, thereby keeping up with the entrance of new providers on behalf of their customers.

WHAT IS INCUBED?

InCubed is a public-private partnership co-funding programme run by ESA's Φ-lab¹⁴ that focuses on developing innovative and commercially viable products and services that exploit the value of Earth observation imagery and datasets.

ESA is however also supporting European Earth observation companies in technology development, payload testing, flight heritage, data science, and the development of commercial services and applications, through initiatives such as the Global Development Assistance (GDA) partnership¹⁵, the Destination Earth programme¹⁶, the ESA BIC network¹⁷ and much more.

The entire value chain is currently affected by a number of business, technological and social trends that are increasing the volume of data being captured. These higher volumes entail an ever greater need to find ways of storing and processing data efficiently, providing insights that will benefit the booming Earth observation analytics platform market.



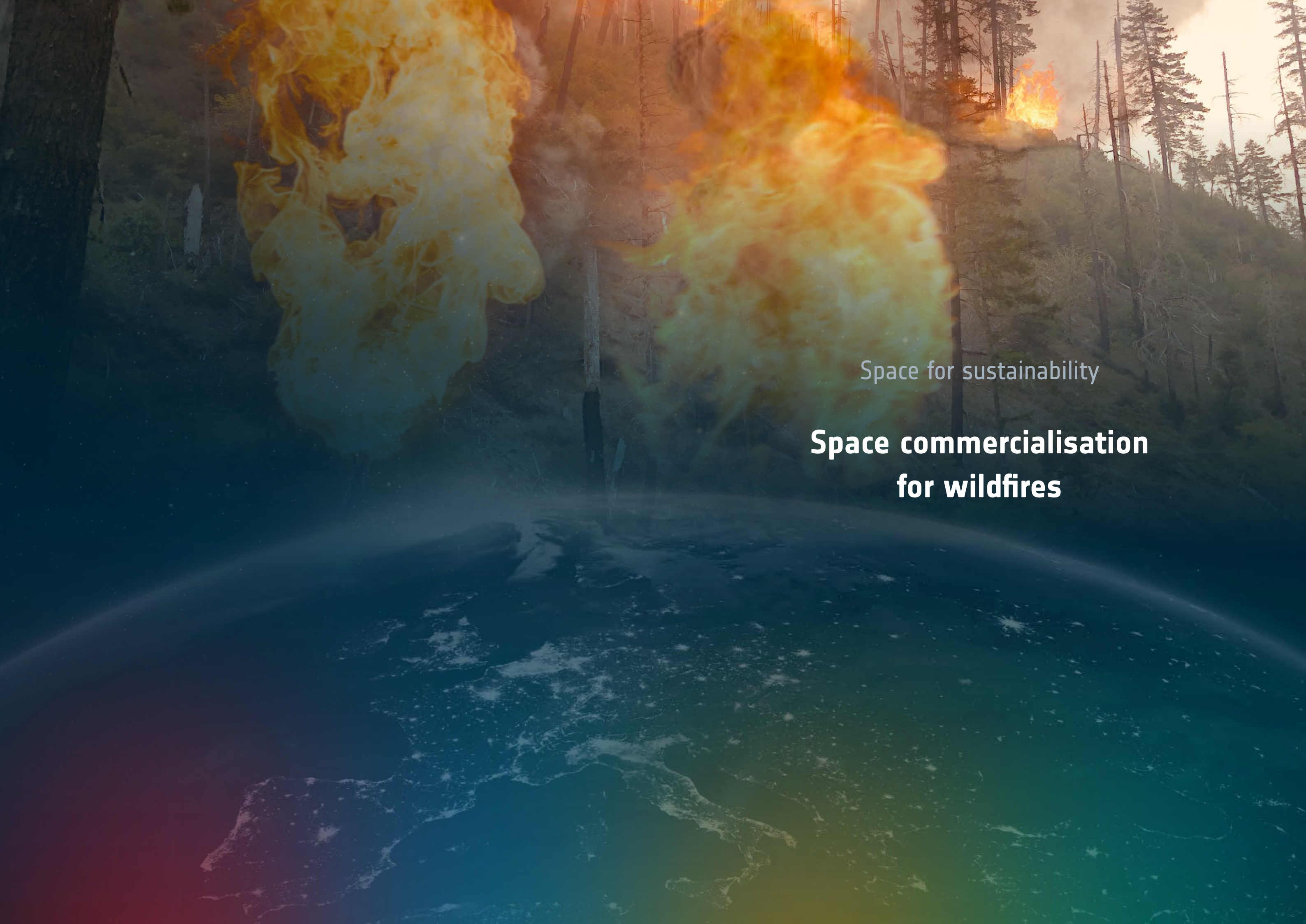
Deepview dashboard showing deforestation free status of a supply chain (visualizing dummy data)

11. www.airbus.com
12. www.iceye.com/press
13. InCubed (esa.int)
14. Φ-lab (esa.int)
15. gda.esa.int
16. philab.esa.int/flagship-programmes/destination-earth/
17. commercialisation.esa.int/esa-business-incubation-centres/

EARTH OBSERVATION VALUE CHAIN OVERVIEW



→ The increasing capabilities of private companies, especially those that have developed EO data analytics platforms, are supported by the main trends driving the development of the Earth observation for environmental monitoring market. The European Space Agency stands ready to spur on that development.

The image is a vertical composition. The top half shows a forest fire with large, billowing plumes of orange and yellow smoke rising from a line of trees. The bottom half shows a view of Earth from space, with the blue and white clouds of the planet curving across the frame. The text is overlaid on the right side of the image.

Space for sustainability

**Space commercialisation
for wildfires**



Space commercialisation for wildfires

Increasing Wildfires and its Costs

With increasing natural disasters worldwide, wildfires and its devastating impact on humans and biodiversity have been drawing attention. The heatwave in summer 2022 has particularly shown the dangers and economic impact of wildfires.

Alone in Spain more than 300k hectares of land had been burned causing costs of almost EUR 3bn according to the European Forest Fire Information System (EFFIS). Spain, Romania and Portugal were impacted the most in Europe. Indeed, 80% of burnt areas are in the countries of the Mediterranean. This number has more than doubled since the 1990s, according to the National Interagency Fire Center. Munich RE estimates worldwide damages through wildfires at USD 24 bn between 2019 and 2021, insurance companies covered around USD 17 bn³.

In the United States, since 2000, an annual average of 70,072 wildfires has burned an annual average of 2.8 million hectares². Similar trends had been seen in Australia, India, or Russia. The recent wildfires in California and Australia caused economic losses over EUR 10 billion each.

Research shows that over 90% of wildfires originate from human activity (e.g. harvesting, land conversation, agriculture, energy lines, conflicts). However, changing weather conditions and extended droughts have led to a considerable increase in wildfire size, frequency and associated impacts.

Country	Hectares burned 2022	CO2 Emitted as a result (tonnes)	Financial Cost
 Spain	293k	2m	€3bn
 Romania	149k	896k	€2bn
 Portugal	103k	620k	€1bn
 France	62k	371k	€639m
 Italy	51k	304k	€523m
 Croatia	33k	197k	€340m
 Greece	22k	133k	€229m
 Bulgaria	13k	76k	€131m
 Hungary	7k	44k	€75m
 Slovenia	4k	26k	€45m
 Germany	4k	26k	€44m
 Ireland	3k	17k	€29m

Hectares burnt as per 6 September 2022. Financial cost is calculated using average cost per hectare. *Illustration citymonitor.ai*¹

1. The cost of Europe's summer of wildfires
2. Wildfires Statistics
3. Waldbrände und Buschfeuer



Multiple Stakeholder Involved in Fighting Wildfires

Firefighting is mainly financed by public money and national as well as regional governments are increasing their budgets as per increasing threats. According to a recent WWF report, the annual budget for forest fires in six Mediterranean countries (Turkey, Spain, Italy, Portugal, France, and Greece) is around EUR 2 billion⁴. France, for example, had earmarked 850 million euros to upgrade its fleet of aircrafts⁵. Greece allocated 75 million euros for measures like clearing forests and roads. Approximately 80% of available funds are spent on suppression and just 20% on prevention. The average cost of suppressing a forest fire in Greece may reach EUR 150,000, while in Canada and the USA it costs EUR 81,000 and EUR 17,000 correspondingly.

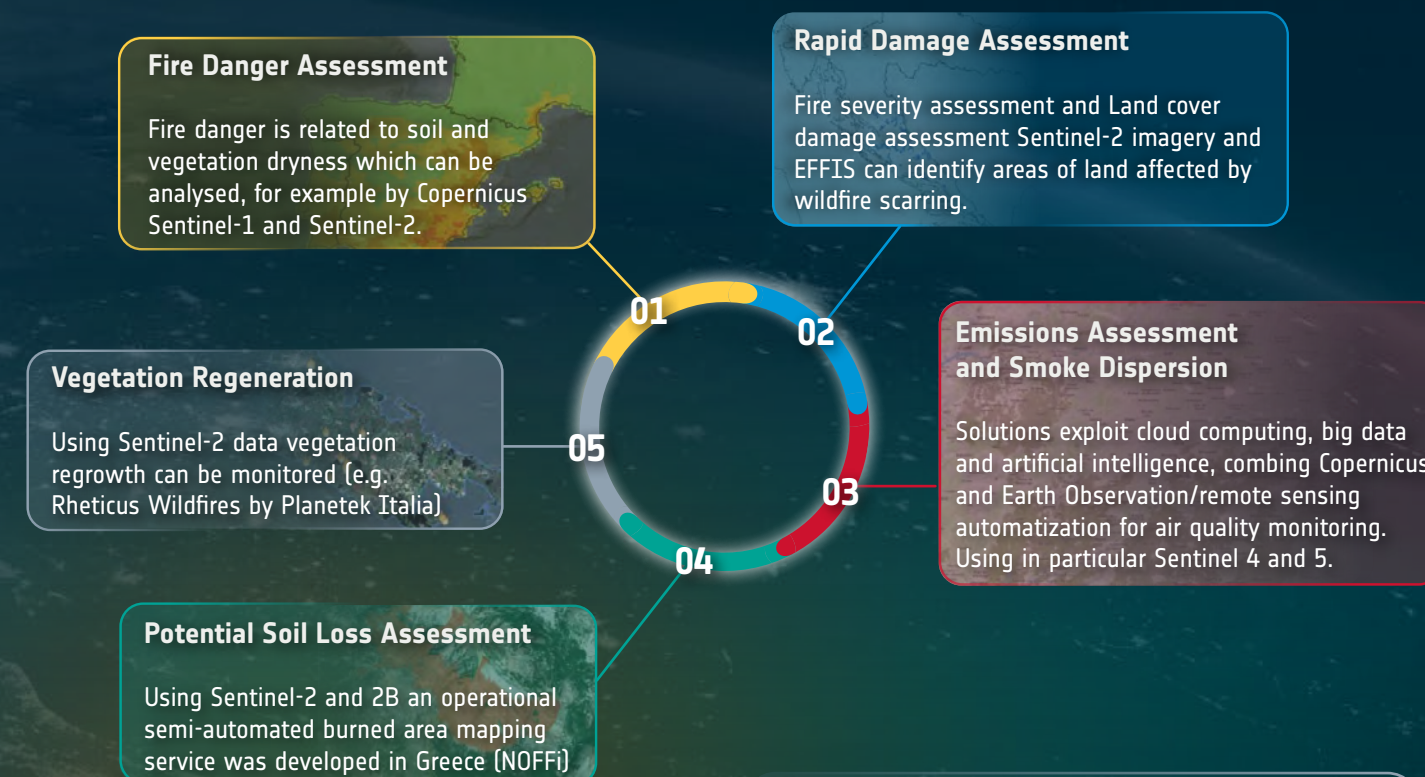
Next to state fire departments, forest owners, reforestation companies, but also insurance companies, real estate developers and energy providers have an interest in decreasing damages by wildfires.

Today, various sources of detecting fires are being used: watchtowers are the most classic option and can be used for forest fire detection locally. Also airplanes may start on a daily basis to watch for devastating fires. Regional volunteering platforms exists to complement these actions. Yet, digital solutions are increasingly supporting the sector: camera networks with AI enabled cloud systems or drones are being used for fire management services, but applications are geographically limited, and more data integration and strategic insights are needed.

Space Added Value by Public Initiatives

Thanks to its ability to see through clouds and wide geographic coverage, space-based solutions, especially Earth observation, are supporting the battle against wildfires. The European public sector, in particular Copernicus, is supporting actors through the European Forest Fire Information System (EFFIS) at European level and the Global Wildfire Information System (GWIS) on global level⁶.

The EFFIS is a web-based information tool with near-real-time and historic data, providing information on the pre-fire conditions and assessing post-fire damages, hence the full fire cycle⁷:



4. Transparency Against Wildfires
5. Wildfires: Europe's latest economic headache
6. EUSPA EO and GNSS
7. European forest fire information sytem



The CAMS Global Fire Assimilation System (GFAS) has estimated that wildfire emission between June and August 2022 has stood at 6.4 megatonnes of carbon, the highest level since 2007. GFAS can estimate the quantity of biomass burned or the emissions of smoke pollutants through satellite observations of active fires and fire radiation power⁸. Further use of Sentinel-2 data focussing on the development and demonstration of burned area

mapping services had been supported in the frame of the Artificial Intelligence for Earth Observation (AI4EO) Wildfires project by ESA⁹.

Various use cases by public administrations using Copernicus data, can be found on the website of NEREUS (Network of European Regions Using Space Technologies)¹⁰.



The pictures shows a Sentinel-2 image: The satellite's shortwave infrared channel was used to highlight heat from a wildfire in western Spain. The Copernicus Emergency Mapping Service was activated and helps civil protection authorities respond to emergencies¹¹.

- 8. Europe's summer wildfire emissions highest in 15 years
- 9. Advanced AI4EO for wildfire monitoring
- 10. User stories sheets
- 11. Wildfire near Salamanca: before-and-after



Commercial Initiatives Are Gaining Traction Worldwide

Dealing with wildfires as a business case is gaining traction: complementing available services with new payloads, higher resolutions or higher monitoring frequencies, commercial players have started developing new solutions and focusing their attention, among others, on forecasting and rapid-fire identification. Google, for example, has announced an expansion of its wildfire services and AI powered detection system in the US, Canada, Mexico and parts of Australia.

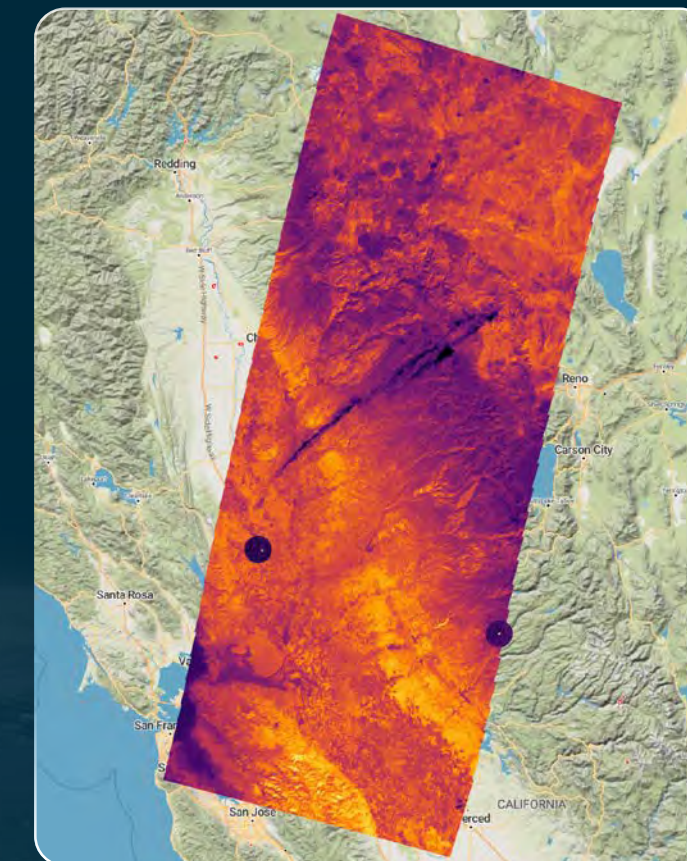
Other actors integrate high-resolution satellite images into their platforms: the collaboration of Maxar and CAPE analytics and its Wildfire Intelligence product suits is an example¹².

CAPE focuses on supporting the insurance industry as it identifies specific risk factors like vegetation clearance, roof construction and material, and proximity to surrounding structures. Hitachi Energy builds on Maxar's satellite imageries to monitor vegetation near power lines, one of the major sources of wildfires¹³. BlackSky and Satlogic offer likewise wildfire services such as damage and change assessments of forests, buildings, and infrastructure¹⁴.

Vertically integrated solutions are also emerging. OroraTech, founded in 2018 and ESA BIC Bavaria alumnus, succeeded its mission FOREST-1: a satellite equipped with RGB, long-wave-infrared (LWIR) and medium-wave-infrared (MWIR) cameras, launched onboard a Spire nanosatellite in January 2022¹⁵.

OroraTech's offering in the market, the Wildfire Intelligence Solution, is leveraging satellite data for wildfire detection & monitoring and precise damage assessment. It is used by clients worldwide, detecting over 1000 fires daily and protecting more than 160 million hectares of forest. With customers from forestry, governments and NGO sectors, OroraTech's solution is used in six continents. Through the ESA InCubed Programme, ESA is supporting OroraTech with its FOREST-3 implementation phase¹⁷.

Interest in thermal infrared imagery is indeed increasing worldwide: British based SatelliteVu is working on a thermal imaging constellation as well as Germany-based Constellr, yet respectively focusing mainly on cities and energy efficiency as well as agriculture respectively, rather than wildfires. Washington-based Hydrosat has raised USD 15 million for its thermal infrared imagery constellation to monitor surface temperatures globally¹⁸. With increasing capabilities of upcoming private constellations, decreasing launch costs and ever better data science potential, private space actors are likely to support the development and implementation of Wildfires detection and mitigation use cases on a commercially sustainable basis and ESA is supporting this development.



The image shows fire detection of FOREST-1 from space over California. The company intends to have a constellation of eight satellites deployed in 2024 with the intention to provide worldwide coverage of high-resolution thermal-infrared imagery.

After that, OroraTech plans to deploy 100 CubeSats to report any fire bigger than 10 meters across the world within half an hour. The expansion of use cases to urban heat, island monitoring and the energy sector is also planned¹⁶. The company seems to gain confidence by investors as it has extended its Series A round with EUR 15M from private investors and public sector co-funding in November 2022.

- 12. CAPE Analytics Expands Wildfire Analytics Coverage to the...
- 13. Connecting the Dots | Wildfires are advancing, but so is satellite...
- 14. Monitor wildfire lifecycle and mitigate risk exposure
- 15. FOREST-1 Mission success: a giant leap for ororatech
- 16. OroraTech launches commercial wildfire detection system
- 17. OroraTech Accelerates Deployment of Its Multipurpose...
- 18. Hydrosat raises \$10 million for thermal infrared imagery...



An aerial view of a city skyline, likely New York City, seen from space. The city is partially obscured by thick white clouds. Below the city, the Earth's surface is visible, showing the ocean and a vibrant rainbow arching across the horizon. The text "Space commercialisation for carbon markets" is overlaid on the right side of the image.

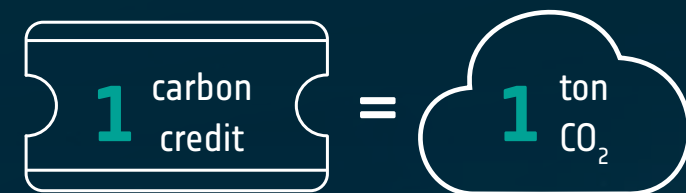
Space commercialisation for carbon markets

Space commercialisation for carbon markets

Introduction to carbon markets

Carbon trading is a cornerstone of international climate change policy, since carbon markets are seen as critical mechanisms to promote the mitigation of greenhouse gas (GHG) emissions (Paris Agreement, Article 6¹). With regulatory and social pressure increasing as the consequences of climate change intensify, the market is booming.

Carbon trading is the process of buying and selling of credits that permit a company or other entity to emit a certain amount of carbon dioxide or other greenhouse gases. Entities must hold a credit for every unit of greenhouse gas they emit. If they exceed their credits, they may face penalties or other compliance measures.



Carbon credits and allowances are traded on carbon markets which are divided into two categories. One category consists of **compliance markets** that are regulated by carbon reduction regimes. In these markets, carbon allowances are used by entities to meet regulatory requirements for reducing greenhouse gas (GHG) emissions. These requirements are enforced through an emissions cap that tends to gradually decrease over time to ensure that emissions continue to fall in the long term. The entities capped at present are the large industrial producers of greenhouse gases. These include industrialised countries, regulated by the Kyoto Protocol, and companies that fall under the EU's or other regional emissions trading schemes. The global compliance carbon market was valued at €865 billion in 2022, with Europe clearly leading the way, as the EU Emissions Trading System (ETS) boasts a market share of 87%². It is followed by North America (WCI and RGGI) at 7%, and the United Kingdom (UK ETS) with 5%. Many other countries have created or are currently developing their own emissions trading schemes, as shown below.

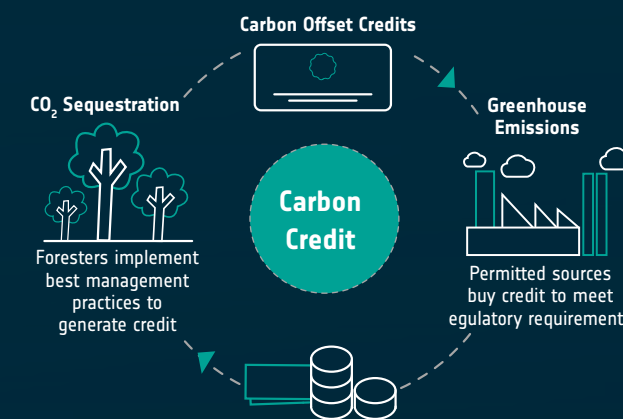


Emissions trading systems (ETS) worldwide in 2023³

1. CLIMATE EXPLAINER: ARTICLE...
2. GLOBAL COMPLIANCE MARKET TRADING...
3. INTERNATIONAL CARBON ACTION PARTNERSHIP...



The other category consists of the voluntary carbon markets (VCMs) which are not intended to satisfy governmental regulations, but are used to reach internal net-zero CO₂ emission targets. VCMs promote innovation and small-scale projects, but are also very fragmented and lack regulatory supervision. This leads to concerns in terms of quality and credibility, which result in increasing claims that some entities leverage carbon-offsetting for greenwashing purposes⁴. Nonetheless, these markets have attracted the interest of corporates and investors alike and in the last few years, a number of companies have started investing in carbon-offset initiatives such as tree-planting schemes. The markets have notched up impressive growth and are expected to climb further, rising from a combined value of \$2 billion in 2022 to around \$100 billion in 2030 and then \$250 billion by 2050⁵.



Critical challenges faced by carbon markets

Carbon projects suffer somewhat from a tarnished reputation, due to a lack of **transparency and reliability** regarding their actual performance, baselines set and benefits achieved.

Reliability has been compromised in recent years. The UNFCCC Kyoto Protocol's "flexibility mechanisms", most notably the Protocol's Clean Development Mechanism (CDM), have a controversial track record regarding their success in actually lowering GHG emissions. Some CDM projects in the past have had adverse social impacts⁹. Research into Verra's carbon standard has also pointed out "phantom credits" that may worsen global heating¹⁰. Moreover, in September 2023, the EU agreed to ban on "climate neutral" claims by 2026¹¹ as companies' communication about their purchase of carbon credits is often misleading and not actually based on proofs of environmental performance.

Proof that carbon was indeed avoided or removed is in fact sometimes difficult to establish. In VCMs notably, the inability to track tree-planting prevents reliable estimates of carbon sequestration and has led to significant failures, such as cancelled projects, or trees dying or being harvested. To ensure that carbon credits adhere to a strict set of standards, carbon projects depend on third-party, internationally-recognised verification standards, such as the Gold Standard, Verra's Verified Carbon Standard, Social Carbon, the Climate, Community and Biodiversity Standards, or standards verified by the UNFCCC. Verra has just recently announced the establishment of the very first methodology in the VCMs that allows for the use of

ZOOM ON EUROPE

Since its creation in 2005, the **EU ETS** has been the central pillar of the EU's policy to combat climate change in a cost-effective manner. It is the world's first major carbon market and is still the largest, even though the emissions allowance sector has developed strongly. At present, it covers over 40% of the EU's GHG emissions and limits the emissions of around 10,000 installations, mainly linked to the energy or manufacturing companies that are currently the principal traders on the carbon market⁶. Financial intermediaries such as banks also trade on this market, usually on behalf of smaller companies and emitters⁷. The market itself is subject to major fluctuations as a result of geopolitical events. In early 2023, for instance, the EU ETS price reached a record high of €100.

Currently in Europe, free carbon credit allowances are granted to energy-intensive companies to protect their competitiveness and discourage them from transferring their production base to countries with weaker climate policies – a process known as carbon leakage. However, the EU is planning to scale back these allowances because they can also remove the incentive to pursue decarbonisation and meet the targets for reducing emissions. Striking a **balance between the risk of carbon leakage and the need to reduce emissions** is currently one of the EU's priorities, and is addressed by the Carbon Border Adjustment Mechanism⁸. To achieve this goal, European countries have recognised and emphasised the importance of international cooperation to link ETS schemes, namely through the International Carbon Action Partnership.

dynamic performance benchmarks and relies on remote sensing data to establish a project's baselines and test its additionality¹². However, current approaches to monitoring and verification are very costly, sometimes making small and medium-sized projects not viable economically.

A more **robust monitoring, reporting and verification (MRV) framework** should be put in place to ensure the quality of these projects. This is particularly important as VCM buyers are increasingly demanding high-quality credits, with 90% of buyers considering MRV as a key purchase criterion¹³. In parallel, regulations must be changed to facilitate the accreditation of companies selling VCM credits.

The effectiveness of carbon markets, and the ultimate success of GHG reduction efforts, depend on the credibility of carbon credits: carbon projects need to be reliable, accurate and transparent to ensure that the claimed carbon credits are genuine and accurately reflect the reduction of GHG emissions. Cost-effective tools to verify carbon projects are therefore essential.

4. GREENWASHING OR A NET ZERO NECESSITY...
5. WHERE THE CARBON OFFSET MARKET...
6. EU EMISSIONS TRADING SYSTEM...
7. ENSURING THE INTEGRITY OF THE EUROPEAN...
8. CARBON BORDER ADJUSTMENT MECHANISM...
9. THE PARIS AGREEMENT'S NEW ARTICLE...
10. REVEALED: MORE THAN 90% OF RAINFOREST CARBON...
11. EU TO BAN GREENWASHING AND IMPROVE CONSUMER...
12. VERRA ANNOUNCES INNOVATIVE, HIGH-INTEGRITY...
13. GEOTHERMAL ENERGY | ICELAND RENEWABLE ENERGY CLUSTER...



How space adds value for carbon markets

One of the overarching issues carbon markets face when tackling the aforementioned challenges is posed by data, which can be unavailable or not systematically reliable, verifiable or environmentally robust. Space-based technologies harbour strong potential in this field, as **satellite images can provide data that is transparent, frequent and covers large areas at low incremental costs**. In addition, as nanosatellite constellations expand, the frequency of measurements increases. By linking the datasets directly to financial systems, daily datasets can be used for tracking trends and changes in the environment and guiding real-time investments and commodity trading decisions.

Most initiatives which aim to use remote-sensing technologies from satellites in the context of carbon projects focus on terrestrial ecosystems, but also coastal and marine, yet carbon sequestration from submerged plants is much more difficult to monitor with satellites.

TERRESTRIAL CARBON ECOSYSTEMS

Forest project monitoring in terms of new trees planted or protected, is one of the main field of applications of space technologies in this context. Biomass and carbon sequestration can be estimated using optical or radar Earth Observation (EO) images from Sentinels, as well as multispectral images. High-resolution hyperspectral images can enrich the analysis of forest

areas by determining tree variety or health, and can also be used to measure crop-soil carbon interaction for **agricultural land**. Future developments are on their way as ESA will be launching the Biomass mission in 2024, carrying a P-band synthetic aperture radar satellite to advance research into the role played by forests in the carbon cycle¹⁴.

BLUE CARBON ECOSYSTEMS

Blue carbon credits correspond to the carbon stored in **coastal and marine ecosystems**, with the main coastal ecosystems being mangroves, sea grasses and salt marshes¹⁵. Although the monitoring of mangroves is more advanced, as illustrated by the Global Mangrove Watch¹⁶ map, the application of blue carbon credits remains in its very early stages of development due to the difficulty of monitoring underwater sectors. Space applications for this sector have progressed through different technologies, with the three main ones being *satellite optical imagery*, which is particularly applicable to mangroves, *LIDAR*, which uses pulsed laser to map ecosystem topography and to collect information on vegetation architecture (such as plant height and biomass that are particularly valuable variables for carbon stock evaluation), and *hyperspectral imagery* that is better suited to identifying vegetation species and health¹⁷. However, more research is needed for the blue carbon credit market to grow, and the present lack of in situ data is challenging progress.

Some space-related initiatives in Europe

RESEARCH AND APPLICATIONS FOR TERRESTRIAL CARBON ECOSYSTEMS

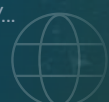
BeZero exemplifies the rising trend of greater integration of satellite monitoring in the VCM¹⁸. This carbon-rating company has recently partnered with **Kayrros**¹⁹, an EO-based service provider, to obtain real time insights on biomass and derive conclusions on the actual effectiveness of voluntary carbon projects, thus improving the accuracy of its carbon ratings. **Treeconomy**, a carbon marketplace which connects landowners and corporate offset buyers, has been exploring EO with the help of ESA BIC UK. The use of satellite EO is intended to complement its drone- and plane-driven assessment of carbon projects to improve accuracy and scalability while reducing costs²⁰. Another approach to the

land area monitoring of carbon emissions and sequestration is offered by **CarbonSpace**²¹. This company currently leverages multispectral satellite imagery coupled with ground station and meteorological data to monitor carbon flux, and is exploring the complementary use of hyperspectral data which captures comparatively more wavelengths.



CarbonSpace technology infographic²²

14. MEASURING BIOMASS IN DEPTH...
15. MITIGATING CLIMATE CHANGE THROUGH COASTAL...
16. GLOBAL MANGROVE WATCH...
17. INNOVATIVE TECHNOLOGY IN BLUE NATURAL...
18. BEZERO CARBON AND KAYRROS...
19. THE LEADING ENVIRONMENTAL INTELLIGENCE COMPANY...
20. UNLOCK NATURE'S VALUE, TO SAVE THE PLANET...
21. ACHIEVE NET ZERO GOALS...
22. SATELLITES' ROLE IN TRACKING THE CARBON...



Forests lost or burned in the Amazon region, mapped on the BeZero Carbon Markets platform¹⁴

The VTT Technical Research Centre of Finland has been leading the **forest carbon monitoring**²³ project under ESA's EOEP-5 programme, so far specifically targeting forest areas²⁴. It has prototyped a set of methods based on optical and radar satellite imaging, mainly sourced from Sentinel-1 and -2, coupled with field data to monitor forest biomass and carbon stock. So far, these methods are more suitable for monitoring at national or regional level, rather than for smaller areas. Other forest applications are emerging such as the solution from ESA BIC France-incubated start-up **Kanop** which aims to facilitate the development and financing of forestry carbon projects by using high-resolution EO to measure carbon sequestration²⁵.

Concerning agriculture, **Green Emissions**, incubated by ESA BIC Sweden, aims to become a voluntary carbon marketplace, using blockchain to enable the satellite monitoring of biomass growth to trigger the payment of carbon credits once the carbon has actually been absorbed²⁶. Green Emissions targets all types of on-land areas, but has decided to focus primarily on cover crops projects. Although often disregarded, these crops protect the soil before winter to prevent soil erosion and nutrient loss, thus enabling the long-term use of the land. Furthermore, the FOCUS project²⁷, kick-started under ESA BASS²⁸, seeks to prove the feasibility of a virtuous economic cycle funding its innovative GAP77 regenerative farming standard through the sale of carbon credits in the VCMs, and carbon insets to coffee companies decarbonising their supply chains.

To help companies reach their net zero strategies, other types of value proposition have emerged. **Kita Earth**, rather than operating as a marketplace, operates as an insurance company

for VCM credits with the support of ESA BIC UK²⁹. It assesses the credits by monitoring the actual carbon removed using AI coupled with satellite images and then comparing the results with the advertised figures.

RESEARCH AND APPLICATIONS FOR BLUE CARBON ECOSYSTEMS

Initiatives targeting blue carbon are much scarcer. Nonetheless, new research projects such as ESA's **Coastal Blue Carbon project**³⁰ have started to appear. This two-year project aims to improve the estimation and monitoring of carbon stock in blue carbon coastal ecosystems by working with end-users (i.e. government agencies, environmental organisations and local communities) through the use of satellite data. Looking into direct applications, **Kuva Space** could play an important role in enabling the growth of the blue carbon credit market in the upcoming years³¹ given its aim to launch the world's largest hyperspectral satellite constellation. Hyperspectral data can be used to verify carbon sequestration and biodiversity in many ecosystems, including coastal areas up to 30 metres in depth, thus enabling the exploration of underwater blue carbon, for which many other satellite technologies are ineffective.



Kuva Space satellite illustration²³

Zoom on the 2023 EO for Carbon Markets Forum

Acknowledging its pivotal role in support to the environmental and climate policies agenda, as well as its role to promote EO technologies and solutions, ESA organised the first-of-its-kind EO for Carbon Markets Forum 2023³² in ESRIN, 3-5 October 2023. Co-organised with key international entities, including DG-CLIMA, DG-JRC, banks and industry, the objective was to promote knowledge exchange and support the development of effective and sustainable carbon markets. It attracted more than 150 participants.

Some of the identified priorities were tools for adaptive forest management, advanced EO methodologies for Carbon Markets fully integrated into finance systems and project operators and certification entities, bioenergy related monitoring and verification, dynamics indices on risks for carbon projects, policy compliance, certification harmonisation, evolution and harmonisation of standards, carbon farming, organisation of EO methodological intercomparisons round-robins.

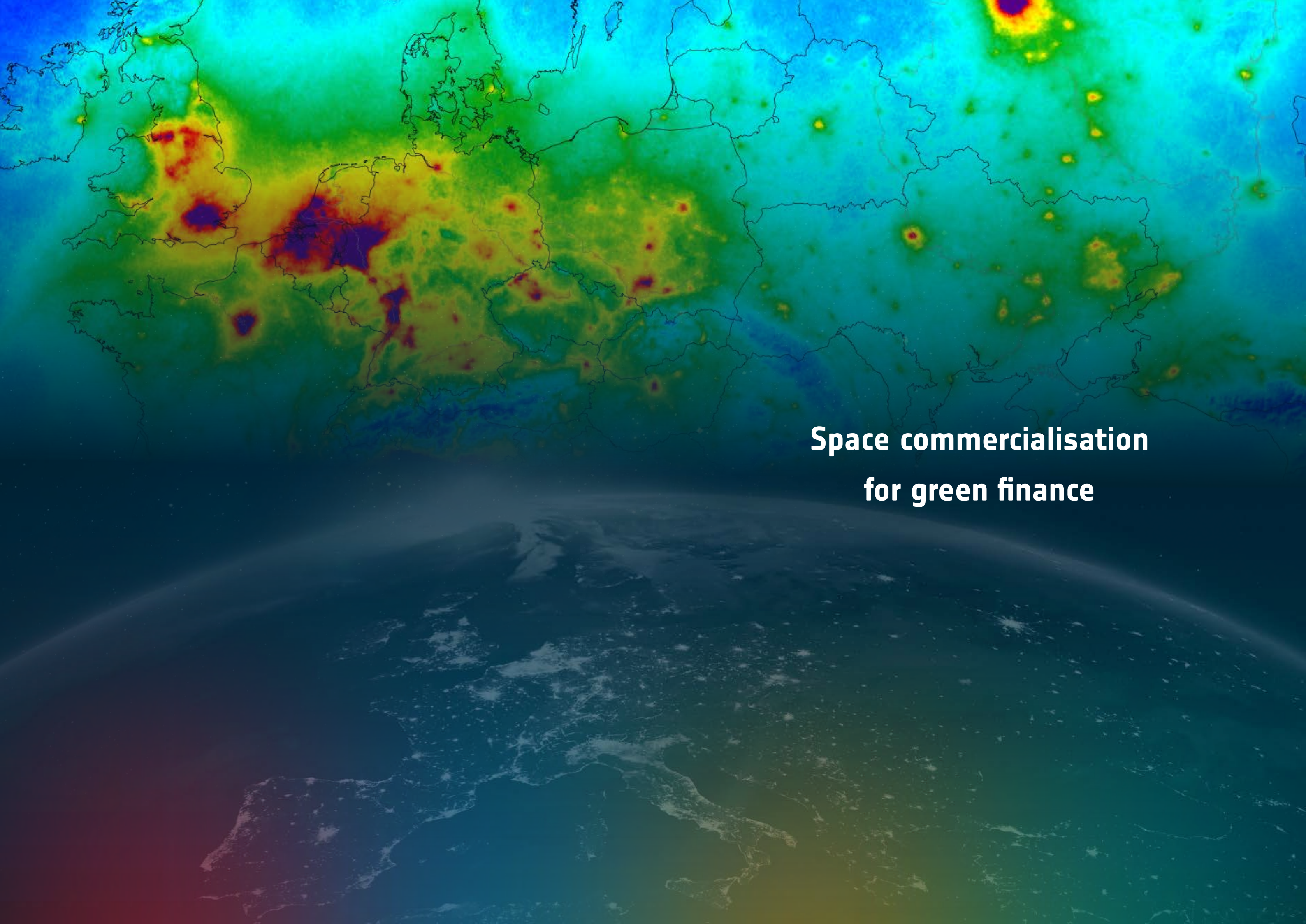


ESA was recognised as a key entity that can, together with commercial data and service providers, de-risk the approaches and enable full operational viable solutions.

Carbon markets are an important tool to accelerate the net zero transition, and satellite data paves the way for more transparent, accurate and low-cost information systems to develop these markets, especially VCMs. ESA supports European companies eager to develop space technology-based solutions for carbon markets across the whole product development cycle: from science-oriented projects (Future EO³³) to start-ups via the ESA BIC Network³⁴, or through projects co-funded under BASS³⁵ or Incubed³⁶.

23. FOREST CARBON MONITORING...
24. EO SCIENCE FOR SOCIETY...
25. DUE DILIGENCE, MRV AND VALUE ENHANCEMENT...
26. FARM AWAY YOUR CO2 EMISSIONS...
27. OBJECTIVES OF THE SERVICE...
28. YOUR BUSINESSPOWERED BY SPACE...
29. REDUCE YOUR RISK. SCALE YOUR IMPACT...
30. COASTAL BLUE CARBON...
31. TRANSFORMING HOW WE UNDERSTAND EARTH...
32. EO FOR CARBON MARKETS FORUM 2023...
33. FUTUREEO...
34. ESA BUSINESS INCUBATION CENTRES...
35. YOUR BUSINESSPOWERED BY SPACE...
36. INCUBED IS AN ESA PROGRAMME MANAGED...





**Space commercialisation
for green finance**



Space commercialisation for green finance

Use Cases and Commercial Opportunities

In finance, space added value has often been linked to specific market analysis on economic activities: oil silo occupancy rates, containers in ports, and cars in front of shopping malls being some well-known examples. Commodity trading and output forecasts for renewable energy markets are also frequently mentioned.

With the financial world's increasing focus on sustainability, new commercial opportunities are emerging. Indeed, corporates and financial institutions are facing increasing pressure to take a more active role in the transition to a sustainable future: greening existing brown assets and financing new green assets. However, Green Finance extends well beyond the asset level to also encompass the environmentally- and climate-friendly design of the financial system as a whole and the management of environmental and climate risks within financial institutions. This imperative has been driven notably by common frameworks such as the Sustainable Development Goals (SDGs) adopted by the United Nations in 2015 as a universal call for social, economic and environmental sustainability, the Paris Agreement that was reached at the UN Climate Change Conference (COP21) in Paris, and an increasing number of non-financial standards for the industry. In particular, the new EU law on deforestation and the "30 by 30" target agreed on during COP15 in Montreal, to conserve 30 per cent of the planet by 2030, will trigger new demands for remote sensing solutions.

With the transformation of the finance sector and emerging needs for nature-related measurements, reporting and verification, space companies are about to become key partners in the short and medium term. This report examines the current status of Green Finance, its main trends, needs and opportunities, and highlights commercial opportunities for space data and technologies. Its findings are based on desk research, semi-structured interviews, and an online workshop attended by more than 17 high-level panellists¹. The document aims to further support the space community in navigating in a new sector and raise awareness on the increasing added value of space.

In fact, insurance- and finance-related data and value-added services are forecast to have a CAGR of 21% until 2031, the highest growth rates of any Earth observation services [1]. New scalable data solutions are needed on an asset, corporate and portfolio level to comply with more stringent government regulations, as well as to respond to growing public pressure. Two main areas of particular interest are emerging: Environmental, Social and Governance (ESG), with a specific focus on the "E" and nature-based solutions. A second report will focus on climate risks and space added value. Sustainability and climate-related data needs are seen as the main segments for the commercial uptake of space data.

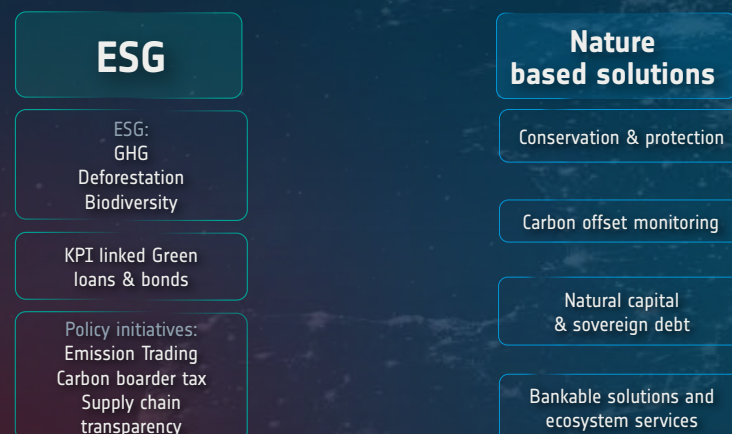


Figure 1: Overview of main green finance use cases identified

1. SPACE FOR FINANCE WORKSHOP: HOW SPACE TECHNOLOGY...



Setting the Scene

The relationship between corporates and their natural environment is twofold: on the one hand the impact of corporates on the environment has to be considered, whether negative, neutral or even positive. In this context, ESG use cases as well as nature-based solutions are of

relevance. On the other hand, private and public financial institutions must manage climate and natural risks and verify whether they are appropriately positioned to respond to long-term climate change and short- as well as mid-term risks from natural hazards.

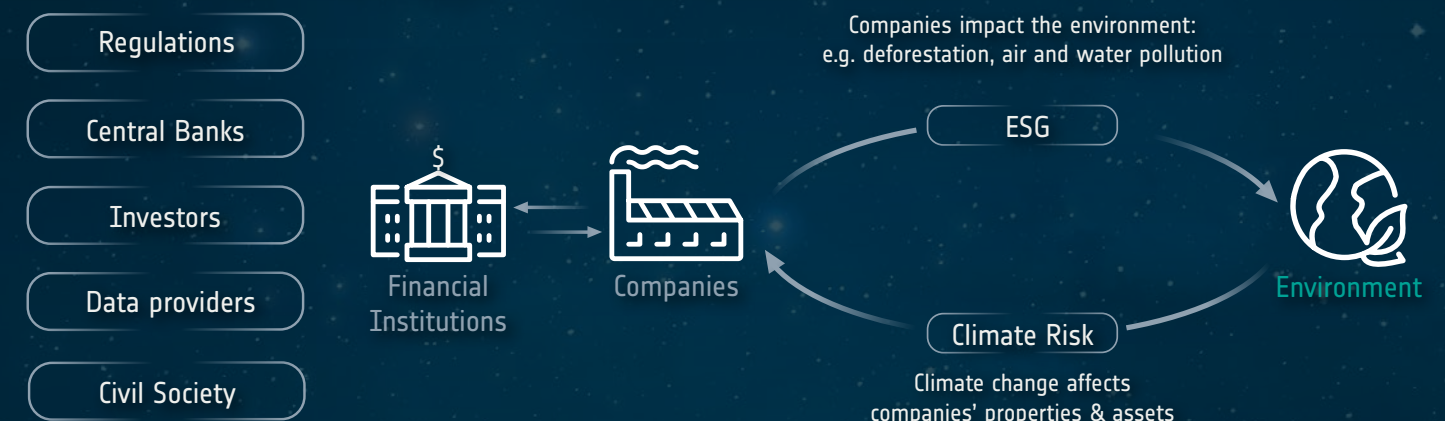


Figure 2: Overview of mutual influence of corporates and their environment

ESG indicators

ESG indicators are data on the sub-asset and asset level. The "E" focuses most particularly on air pollution monitoring and increasingly on areas such as deforestation, biodiversity and water-related pollution. ESG indicators are relevant for credit and investment due diligence and portfolio analysis, increasingly carried out by growing ESG or sustainability teams within financial institutions. While theme- and impact-related investments are still relatively small-scale, they have seen high growth rates in recent years. The estimated current size of the global impact

investing market stands at US\$715 billion [3]. The majority of the total assets under management in sustainable funds are currently held by institutional investors, even though the share held by retail investors is increasing. For the future, assuming 15% growth, half the pace of the past five years, Bloomberg predicts ESG assets under management could represent more than a third of the projected total US\$140.5 trillion global total assets under management by 2025.

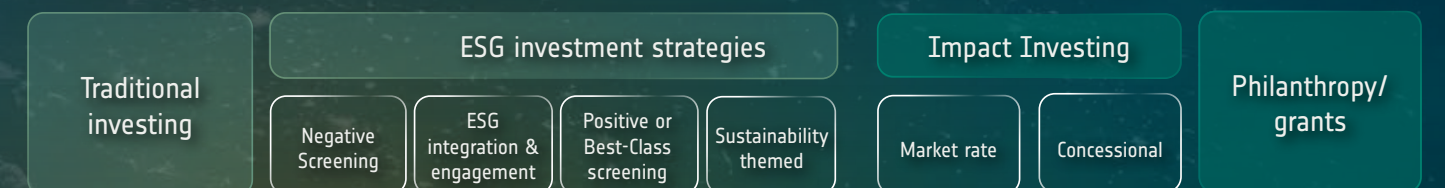


Figure 3: Overview of different investment types, based on GISD Alliance 2020

At the heart of the ESG discussion is the information asymmetry between corporates and their external stakeholders, which include investors, governments, and civil society. Companies themselves often lack the processes to report on how their operations or investments impact on or depend on nature, especially along their own supply chain. Stakeholders depend on voluntary disclosures, often issued once a year, with all the potential issues this entails with regard to accuracy, coverage, and granularity.

In response to increasing public interest and regulatory pressures, an entire industry has sprung up to fill the gap made up of start-ups, rating agencies, as well as consulting, data and engineering companies that analyse and score companies. However, these ratings rarely focus on real (environmental) impact assessments, but instead are based on scoring models placing a greater weight on the “G” part of ESG. As a consequence, science-based targets and real impact measurements as well as tools aligned with international standards are beginning to emerge: a new generation of specialised data providers focuses on alternative data sources and leverages innovative technologies from natural language processing through machine learning to spatial monitoring.

In addition to the information asymmetry, dozens of different ESG disclosure frameworks exist. The most relevant, the “group of five”, have made important strides towards developing common standards: the **Carbon Disclosure Project (CDP)**, the **Integrated Reporting Framework**, the **Climate Disclosure Standards Board**, the **Global Reporting Initiative**, and the **Sustainability Accounting Standards Board**. Frameworks are often built on recommendations by the Task Force on Climate-Related Financial Disclosures (TCFD) or the Network for Greening the Financial System (NGFS). The goal is to develop common standards on how data are gathered, how metrics should be created and the way in which materiality should be incorporated. These are relevant for financial supervisors, central banks, banks or investors.

An important driving force for new data demands has been the tightening of regulatory environments: one example is article 29 of the French law on Energy and Climate, which requires all French financial institutions to disclose their approach on biodiversity-related and climate-related risks from 2022². Widely impactful are the new European regulations on sustainability-

related disclosure: the **European Union (EU) Taxonomy** is a classification system established to clarify which investments are environmentally sustainable. It came into force in 2020 and has been applicable since 2022. The EU Taxonomy goes hand in hand with the Non-Financial Reporting Directive for corporates and the Sustainable Finance Disclosure Regulations (SFDR) for financial market participants. The UK is working on a separate taxonomy. With these taxonomies, Europe is establishing some of the most stringent rules worldwide. Transparency demands on value chains, like Scope 3 emissions or regulations on deforestation, in particular, are creating new data demands.



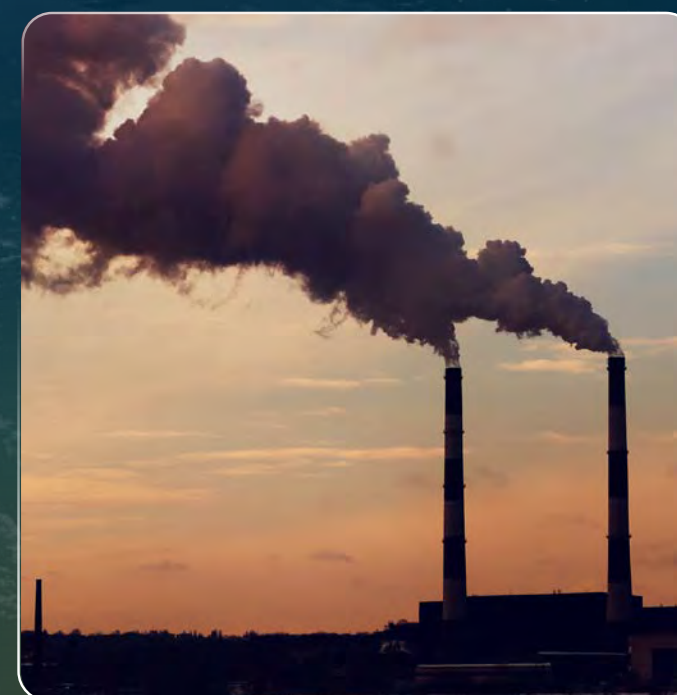
2. French investors had to disclose their climate-related risks on a comply-or-explain basis already since 2016. More details on Article 29 in French under: DEVELOPING AND DELIVERING A RISK MANAGEMENT AND... The Banque de France has created a climate change centre in April 2021 to understand and improve the climate and ESG performances of banks' portfolios.

ESG-related Use Cases

Pressure on companies to cut emissions is high, not only since the Dutch landmark ruling ordering Shell to reduce its carbon emissions by 45 percent by the year 2030 [4]. Regulations are focused on the reduction of carbon emissions in response to reputational, regulatory and transition risks. Emissions are categorised as direct (“scope 1”), energy-related (“scope 2”) and indirect (“scope 3”).

At present, there are two main market types in need of data: compliance and voluntary markets – with substantial variation by region and sector, while obligatory reporting of Greenhouse Gases (GHG) emissions is often limited to large, listed corporates.

The dominant standard for self-reported carbon accounting is the GHG Protocol Corporate Accounting and Reporting Standard (“GHG Protocol”). The GHG Protocol, is currently used by 9 out of 10 Fortune 500 companies. Science-based targets, meanwhile, are being developed by the Science Based Targets Initiative. Cost-efficient monitoring of SMEs and corporates in low- and mid-income countries, in particular, remains a challenge. Nevertheless, voluntary carbon markets have seen growth in recent years, driven by net-zero commitments. A recent survey estimated that the voluntary market has an opportunity to grow 15-fold by 2030 [5]. Dedicated carbon emission disclosure projects and commercial platforms are the CDP, Four Twenty Seven (part of Moody's), S&P Trucost, the 2° Investing Initiative, and Transition Pathway Initiative, among others [6].



Despite some progress having been made, emissions levels are based on sparse data creating wide divergence in estimated emissions. Results often provide high-level assumptions that are not based on accurate baselines and with an inability to track changes and progress – or even reward those where they occur. Asset data and attributes are available commercially for a few sectors to a limited degree such as mining, shipping, oil and gas, power plants, fishing and real estate. These data platforms are mostly commercial – so only accessible at a cost – fragmented, and fail to cover all regions, sectors and assets. Gaps are filled by models and indirect measures (Environmental Extended Input Output matrix, regression models, life-cycle data, among others). Scope 3 emissions have the lowest coverage of all disclosures: according to CDP, fewer than half of the companies that disclose emissions data actually track and report on scope 3 emissions.

While carbon dioxide has received most attention, methane emissions are the second largest cause of global warming. The energy sector – including oil, natural gas, coal and bioenergy – is among the largest sources of methane emissions, but efforts to reduce them have often been hampered by a lack of reliable data [7]. The Climate and Clean Air Coalition, a voluntary partnership dedicated to reducing short-lived climate pollutants, or the Global Methane Alliance are emerging forums gathering stakeholders for information exchange. In 2021, the United Nations Environment Programme UNEP and the European Commission joined together to launch the International Methane Emissions Observatory [8]. It will, among other things, aggregate company reporting, satellite data, and measurements from scientific studies.

Furthermore, financial products linked to emission reduction KPIs exist, but are limited in use (e.g. KPI-linked bonds or loans). Industry experts expect a further growth in these instruments and an increasing need for data for monitoring and evaluation.

Emissions Trading Systems and Carbon Border Adjustment Mechanism

Carbon market mechanisms put a price on carbon and help to internalise the environmental and social costs of carbon pollution. An **Emissions Trading System (ETS)**, also known as a cap-and-trade mechanism, sets a mandatory limit or cap on GHG emissions for a predefined set of sectors. ETSs exist at regional, national and sub-national levels and cover various sectors [9]. China's emissions trading system came online in 2021 and is currently the largest carbon market in the world, covering around 4,000 Mt CO₂ or 30% of its national GHG emissions. The EU ETS covers all EU countries (as well as Iceland, Liechtenstein and Norway) and around 2,000 Mt CO₂ of emissions. Apart from the EU, four countries have enacted national-level GHG ETSs: New Zealand, Switzerland, Kazakhstan and the Republic of Korea. Other countries have announced plans for these systems. ETSs rely on GHG reporting systems with monitoring, reporting and verification requirements. Digital

technology innovations can be used when generating and trading carbon credits efficiently, as well as improving access to better data and analytics and helping create well-functioning markets.

A **carbon border adjustment mechanism**, also called carbon import tax, was presented in 2019 as a key measure of the Green Deal. The European Parliament gave the green light for a pilot to be set up by 2023 to charge imported carbon-intensive goods³. While legal and trade implications are being intensively discussed, emission data collection, monitoring and verification remain important operational questions to be clarified. As countries have very different approaches to measuring GHGs, and only a few functioning ETSs are in place in low- and middle-income countries, objective monitoring and verification systems will be required.

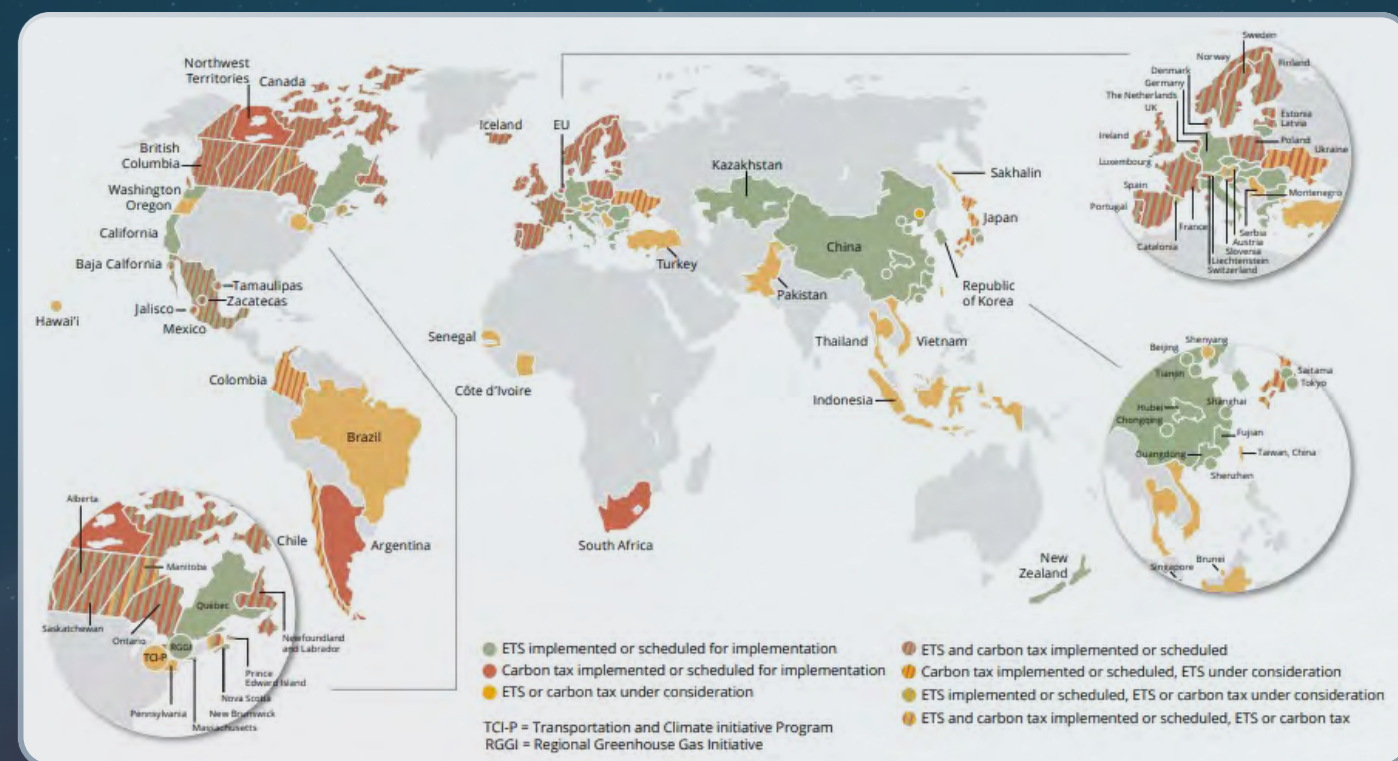


Figure 4: Areas and types of carbon pricing schemes, World Bank, 2021

3. A high level conference on this topics was organised in March 2021 in Paris by the French government. Recordings are available here: [VIDÉO] CONFÉRENCE « UN AJUSTEMENT CARBONE AUX...

Deforestation

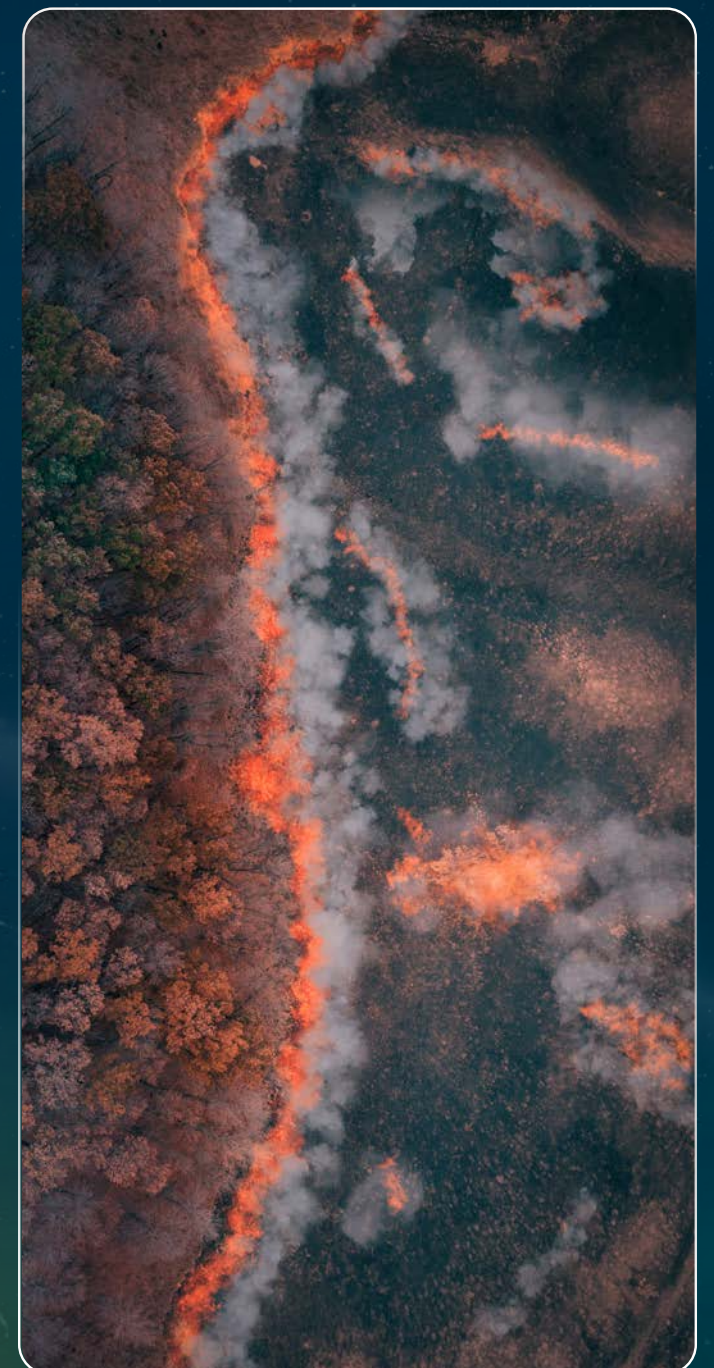
Signatories of the New York Declaration of Forests agreed to "at least halve the rate of loss of natural forests globally by 2020 and strive to end natural forest loss by 2030". Yet, global deforestation currently represents around 10 million hectares per year and nearly 10% of global tree cover has been lost since the turn of the century alone. Agricultural expansion is the main driver of deforestation, especially agricultural commodities – cattle, oil palm, soy, cocoa, rubber, coffee and plantation wood fibre – together they accounted for more than half of global tree cover loss from 2001 to 2015 according to a recent study using spatial data [10]. Cattle replaced most forests by far (45.1m hectares), followed by oil palm (10.5m hectares) and soy (8.2m hectares) [11]. Overall, Brazil, the Democratic Republic of the Congo, Bolivia, Indonesia, and Peru were among the top 5 worst-hit countries for primary forest loss in 2020. In the Brazilian Amazon rainforest, deforestation hit a twelve-year high in 2020. While progress in eliminating palm oil-related deforestation is being made, cattle products and soy supply chains are lagging behind [12].

Companies, but also financial institutions (FIs), are facing challenges in assessing, monitoring and managing their deforestation risk exposure across the value chain, especially in remote areas. In addition, investment flows and supply chains are often long and complex. In the case of palm oil, coffee and cocoa, many small farmers are involved. Local national regulations are diverse and even if deforestation may be illegal in many regions, it is not necessarily prosecuted [12].

Important data sources are Global Forest Watch (GFW) and the United Nations Food and Agriculture Organizations' Global Forest Resources Assessment 2020. Key for FIs is the matching of assets and investments with deforestation activities as is done by Forest 500, which allocates scores both to companies and to FIs. The Dutch Sustainability Finance Platform recently published guidelines on how to handle deforestation for FIs. These guidelines include useful tools and available satellite-based solutions that have been rated the most useful for monitoring and reporting.

Stricter regulations are emerging in most developed economies. The European Commission, for example, proposed in a recent communication the creation of a multi-stakeholder platform and an EU Observatory on deforestation and forest degradation, also focusing on

redirecting finance to support more sustainable land-use practices [13]. In 2022, the EU agreed on laws to fight global deforestation and forest degradation driven by EU production and consumption⁴. Operators and traders will have to prove that products are both deforestation-free and legal, which will consequently increase demand for precise geographical information.



4. GREEN DEAL: EU AGREES LAW TO FIGHT GLOBAL DEFORESTATION...

Biodiversity

Human pressure on the natural environment together with climate change give rise to challenges such as deforestation, pollution, overharvesting as well as a proliferation of invasive species, which in turn can lead to biodiversity loss. In response to the alarming rate of biodiversity loss worldwide, the UN has initiated the Decade on Ecosystem Restoration 2021–2030 to ensure countries deliver on their commitments to restore one billion hectares of land⁵. Still, most economic activities depend on and have an impact on biodiversity and ecosystem services, directly or indirectly. FIs need to understand their exposure to biodiversity-related financial risks and identify opportunities for mitigation. FIs can also enhance biodiversity through conservation or ecosystem restoration financing. The Dutch Central Bank and financial supervisor, De Nederlandsche Bank, became the first central bank to highlight biodiversity as a material financial risk⁶. Since 2022, French FIs have been required to disclose how they will identify, prioritise and manage climate and biodiversity risks [14]. In May 2020, the EU released a new Biodiversity Strategy for 2030, which includes legally binding targets for restoration of carbon-rich habitats. At the COP₁₅ summit, the 30 by 30 target had been set with the aim of protecting 30 per cent of the world's land and sea by 2030 to, in turn, reduce biodiversity losses. However, it remains the case that precise universal metrics and KPIs for measurement do not yet exist.



For the time being, data are the biggest hurdle for investors trying to address biodiversity as measurable biodiversity-linked targets have not yet been defined [15]. In a survey, some 72% of 270 respondents said they have performed no assessments on their investments' impact on biodiversity whatsoever. While some banks and investment funds publish research papers and strategies, a standardised approach to biodiversity protection or even investments will probably still take years to emerge⁷. Even if FIs knew what they wanted to measure, the lack of biodiversity data would make it challenging to do so in practice [14]. Measuring biodiversity variables on the ground, such as species populations and ecosystem function and structure, is time and resource extensive. ALIGN (Aligning Accounting Approaches for Nature) and PBAF (Partnership for Biodiversity Accounting Financials), among others, propose measurements and related data [16].

Still, projects are already under way to better understand the impact of finance on nature and the related measurement solutions. The NGFS and INSPIRE, for example, have launched a joint research project on "Biodiversity and Financial Stability" to better understand the impact of finance on the provision of key ecosystem services as well as the consequences of biodiversity loss for financial stability [17]. The ENCORE tool (Exploring Natural Capital Opportunities, Risks and Exposure) developed by the Natural Capital Finance Alliance has been mentioned in various consultations, together with the Integrated Biodiversity Assessment Tool (IBAT). Besides the idea of protecting biodiversity, investors are becoming increasingly aware of the important material and systemic risk arising from their investments [19].

5. On international level, biodiversity is likewise being addressed by the SDGs, the Aichi targets and the post-2020 negotiations of the convention on Biological Diversity. The new EU Biodiversity Strategy 2030 stresses the need to integrate biodiversity considerations better into public and business decision-making.

6. A study concluded that Dutch financial institutions' portfolios consist of 36% of companies with high or very high dependency on one or more ecosystem services.

7. For example: WWF France and AXA recommendations for the... and BNP Paribas: SUSTAINABLE BY NATURE: OUR...



Nature-based Solutions

There is a growing interest to not only limit the negative impact on nature, but also to protect it and invest with a view to having a positive impact in **nature-based solutions**. These solutions aimed at having a positive impact on nature are notably supported by emerging technologies for stocktaking, location identification, impact assessments, and monitoring. Yet, current investments in nature-based solutions⁸ amount to a mere US\$133 billion annually⁹— about 0.10 per cent of global Gross Domestic Product, most of which comes from public sources (86%) [18]. In addition, carbon offsetting is developing as a commercial business, either on a voluntary basis or by means of emissions trading systems.

Of the public annual investments of US\$115 billion, over a third is invested by national governments in the protection of biodiversity and landscapes. Private sector commitments are estimated at around US\$18 billion per year. This includes activities such as biodiversity offsets, sustainable supply chains, private equity impact investment and smaller amounts from philanthropic and private

foundations. However, such investments are perceived as high risk, low return and difficult to monitor. There is a general lack of "labelling, tracking, reporting and verifying" the state of finance for nature-based solutions.

New approaches are needed to improve data comparability and quality, as an input to future decision making (e.g. stock taking, location identification, impact assessments and monitoring). Continued growth in carbon offsetting as well as carbon credits, brought about by sustainability concerns as well as the rise of ETSs worldwide, can be expected to drive data demand from satellites, drones and low-flying aircraft. Blockchain can be one way to establish reliable linkages between national registry systems and the Paris Agreement. This includes token systems such as the Microsoft-backed InterWork Alliance initiative and the CBL Nature-Based Global Emissions Offset contract by AirCarbon and ClimaTrade. The World Bank through its Climate Warehouse also offers a public data layer connection to attached registry systems.



Estimated overview and classification of Nature-based solutions finance, UNEP, 2021

- Domestic Government
- Private Capital
- Public ODA

8. A study concluded that Dutch financial institutions' portfolios consist of 36% of companies with high or very high dependency on one or more ecosystem services. WCC-2016-RES-069-EN DEFINING NATURE...

9. Estimates do not cover all types of nature-based solutions, with notably those in the marine environment excluded, despite their importance.

BANKABLE SOLUTIONS AND PAYMENT FOR ECOSYSTEM SERVICES

The market is estimated to stand at US\$51m annually. Governments and Multilateral Development Banks (MDBs) are looking at how to incentivise landowners by payments to protect watersheds, conserve biodiversity or restore natural carbon through forests, replanting trees or sustainable agriculture, but also infrastructure resilience, especially in coastal areas. Water trading services, for their part, are focused on setting up schemes to enhance water quality or availability.

The EIB, for example, manages the Natural Capital Financing Facility supporting conservation and bankable nature-based solution projects as an alternative to grants. Such projects may focus on sustainable forestry, sustainable agriculture (e.g. pollinator-friendly agriculture), sustainable aquaculture, ecotourism (e.g. sustainable wild fishing), carbon sequestration or green infrastructure¹⁰. In addition to the EIB, other MDBs, as well as the World Wide Fund For Nature (WWF) are looking at bankable nature-based solutions that can generate positive impacts on nature and positive financial return. The discussion on bankable nature-based solutions and ecosystem services is far from new, but has garnered renewed attention in recent years. Moreover, since the 1990s, nature for debt swaps have...¹¹. While in recent times only a few transactions have been carried out worldwide, debt burden and recovery plans in a post-COVID world could trigger fresh interest in joint nature protection and the related reporting needs to investors.

WEALTH ACCOUNTS AND SOVEREIGN DEBT

The World Bank, together with other stakeholders, has highlighted the fact that the lack of integration of natural capital in public national wealth accounts fails to reflect national wealth fully, but also the associated risks [19]. In March 2021, the United Nations Statistical Commission

adopted SEEA Ecosystem Accounting (SEEA EA), a new framework that includes the contributions of nature when measuring economic prosperity and human well-being, as well as ensuring that natural capital, forests, wetlands and other ecosystems are recognised in economic reporting¹². In "Making Peace with Nature", the UN states how a three-fold increase in the extraction of natural resources has fuelled economic growth over the last 50 years [20]. For now, more than 34 countries are in the process of compiling ecosystem accounts on an experimental basis. While the new framework might motivate more countries to implement similar accounting systems, the UN acknowledges that "a significant number of countries will require assistance and additional resources for statistical data collection".

Dependency on nature to generate economic wealth is peculiarly high in developing countries. In fact, natural capital constitutes almost half of the wealth in low-income countries and more than a quarter in lower- and middle-income countries. Nevertheless, investors consider mainly political and social factors in their risk profile when assessing sovereign debt [21]. A recent report by the WWF and Investec Asset Finance has shown how sovereign debt investments fail to comprehensively integrate environmental issues, despite the reliance on natural capital for many key industries. The report argues that advances in geospatial data and satellite imagery could help sovereign debt investors better assess and manage environmental risks while also supporting research, security valuation and portfolio management. The UN Principles for Responsible Investment have established guidelines and collected a sample of freely available environmental data sources to integrate ESG in sovereign debt analysis. The World Bank's sovereign ESG portal is already working with various geospatial data inputs with the support of ESA¹³.

10. The EIB Paper "Investing in Nature: Financing conservation and nature-based solutions" highlights some of these examples in more detail.

11. The Seychelles were burdened by a heavy sovereign debt load and rising sea levels. In a PPP, Nature Conservatory Fund and a group of philanthropists restructured the existing debt to implement the Marine Spatial Plan and conserve 40,000km of marine area.

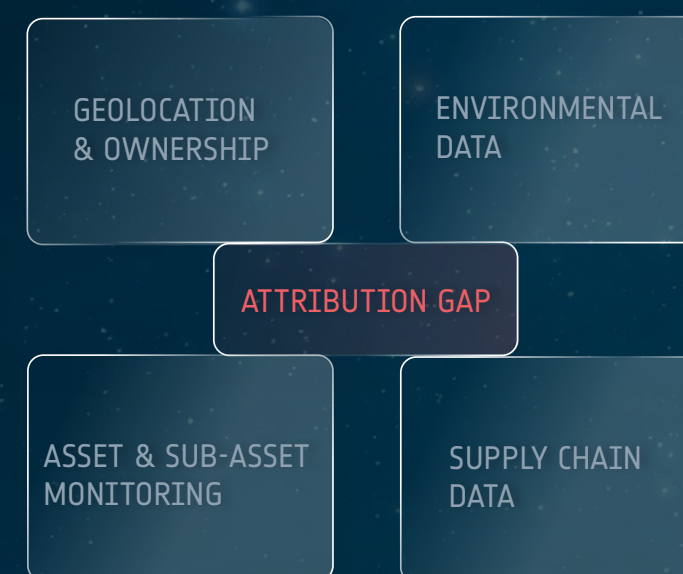
12. SYSTEM OF ENVIRONMENTAL-ECONOMIC ACCOUNTING—ECOSYSTEM...

13. ENVIRONMENTAL, SOCIAL, AND GOVERNANCE DATA... with support from the EO Clinic "Natural Wealth and Sovereign Risk: NATURAL WEALTH AND SOVEREIGN RISK



Green Finance Needs

Most of the relevant needs associated to ESG and nature-based solutions revolve around questions of geolocation and ownership, asset and sub-asset monitoring, reliable environmental data and supply chain transparency.



Geolocation and ownership: Asset data and attributes are available commercially for a few sectors and only to a limited degree (e.g. mining, shipping, oil & gas, power plants, real estate). Relevant attributes of assets can be age, capacity, ownership and geospatial coordinates. It is especially the lack of geospatial information in credit and investment deals, as well as their disclosure, that is a major obstacle to producing scalable solutions, but also to closing the attribution gap to environmental change. There are no general systems in place allowing for asset data exchange between actors [22]. Business intelligence providers hold databases on company tree level and universal IDs exist to a certain degree (e.g. GLEIF Legal Entity Identifier - LEI or Refinitiv), yet open source solutions remain limited [22].

Asset and sub-asset monitoring: Companies will need new Internet of Things (IoT) connectivity solutions and digital platforms to understand the environmental impact of their activities ranging from air and water pollution to landscape changes and biodiversity. An understanding of point-in-time performance of an exposure against a

transition pathway as well as monitoring of the impact of adaptation and mitigation measures is needed [23]. Mechanisms for verifying and auditing climate-related financial disclosures are essential to making data reliable and comparable [23]. Air pollution and in particular methane emission monitoring and tracking, as well as deforestation, are of the greatest interest at the present time. During the COVID-19 crisis, on-site inspections for due diligence or monitoring have been limited.

Environmental data: Consistent, frequent, accessible and inexpensive climate and environmental data in high resolution is needed as well as converting qualitative information into quantitative data points. This also includes the proximity to cultural or natural sites or protected areas such as rivers, wetlands, forests, or endangered species and their status and development [22]. Reliable, cost-efficient location identification, implementation, monitoring and verification is needed for nature-based solutions. Regional and national administrators require reliable, up-to-date data for statistical purposes.

Supply chain transparency: The lack of geolocation data and limited company disclosures make collecting supply chain data a challenge. This is relevant when it comes to emissions across all industries, but is also highly relevant for commodity value chains, and especially for deforestation. Few general national or sector databases exist, but those that do are not connected, nor do they specify environmental impact. Greater specificity, supply-chain tracking, interconnectivity and models for risk probabilities are needed [22].

Space Added Value and Synergies

Space infrastructure can look back on decades of successful climate and environmental data collection, monitoring and insights. The Oxford Sustainable Finance Group at the University of Oxford and activities by the World Bank and WWF provide the most advanced examples¹⁴. It is also true for leveraging satellite data to create asset-level datasets and carry out climate risk analysis¹⁵. International financial institutions and rating agencies

integrate spatial ESG data with the aim of gaining better data, understanding correlations, and monitoring project success. The Spatial Finance Initiative, which aims to integrate geospatial data and analysis into financial theory and practice, sees considerable growth potential in the ESG data, environmental and nature and biodiversity markets – in comparison to more mature spatial finance solutions.

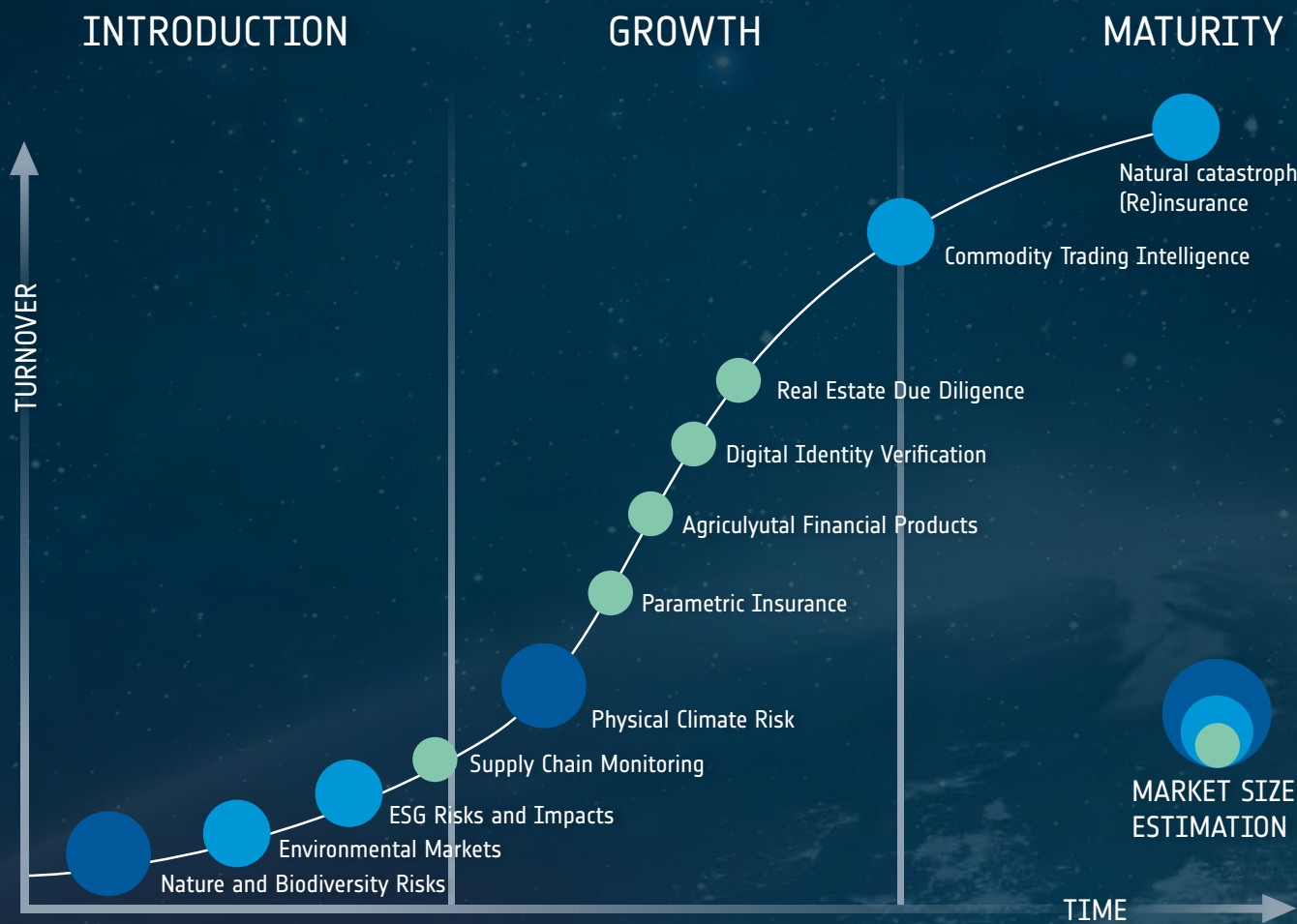


Figure 6: Maturity and addressable market size for spacial finance solutions, Spatial Finance Initiative, 2021

14. Catapult collected main sustainable finance market sources with links to space added value: SUSTAINABLE FINANCE MARKET INTELLIGENCE...

15. See for details "Climate risk analysis from space: remote sensing, machine learning, and the future of measuring climate-related risk": CLIMATE RISK ANALYSIS FROM SPACE...

As set out in ESA Agenda 2025, the European Space Agency is focusing its efforts more than ever on supporting green, sustainable solutions as well as on leveraging public and commercial space infrastructure and knowledge. Some of the use cases highlighted have already been addressed by ESA¹⁶, often in the framework of cooperation with MDBs¹⁷, but also with commercial stakeholders. MDBs operate with the goal of creating positive impacts and work under specific monitoring and evaluation guidelines¹⁸. The ESA Sustainability Office provides support to the World Bank's Sovereign ESG Data Portal¹⁹ through the ESA Global Development Programme. Experience from nature-based solutions can also be transferred to further address emerging commercial needs.

The added value of spatial data lies in its high frequency, quality, comparability, consistency and scalability as highlighted by the Spatial Finance report of the World Bank and WWF [22]. Space companies have highlighted the momentum of an emerging structural integration

with the finance sector, beyond pilot and project-based work. Indeed, space infrastructure can contribute to filling ESG data gaps, specifically with regard to environmental ESG parameters and nature-based solutions and ensure connectivity of local sensors on asset or sub-asset level (and integration with 5G/6G) as well as geolocation of assets. Existing public infrastructure, such as Copernicus and Galileo, are building the basis of derived commercial applications and services and are being increasingly complemented by private constellations.

Space companies fill existing market gaps and provide solutions for corporates and financial institutions to better understand and manage their environmental impact and reporting on sub-asset, asset and corporate level, but also along the supply chain. European Earth observation and data processing companies already provide considerable value to the further development of the sector. A snapshot of some of the relevant actors can be seen in the figure below.

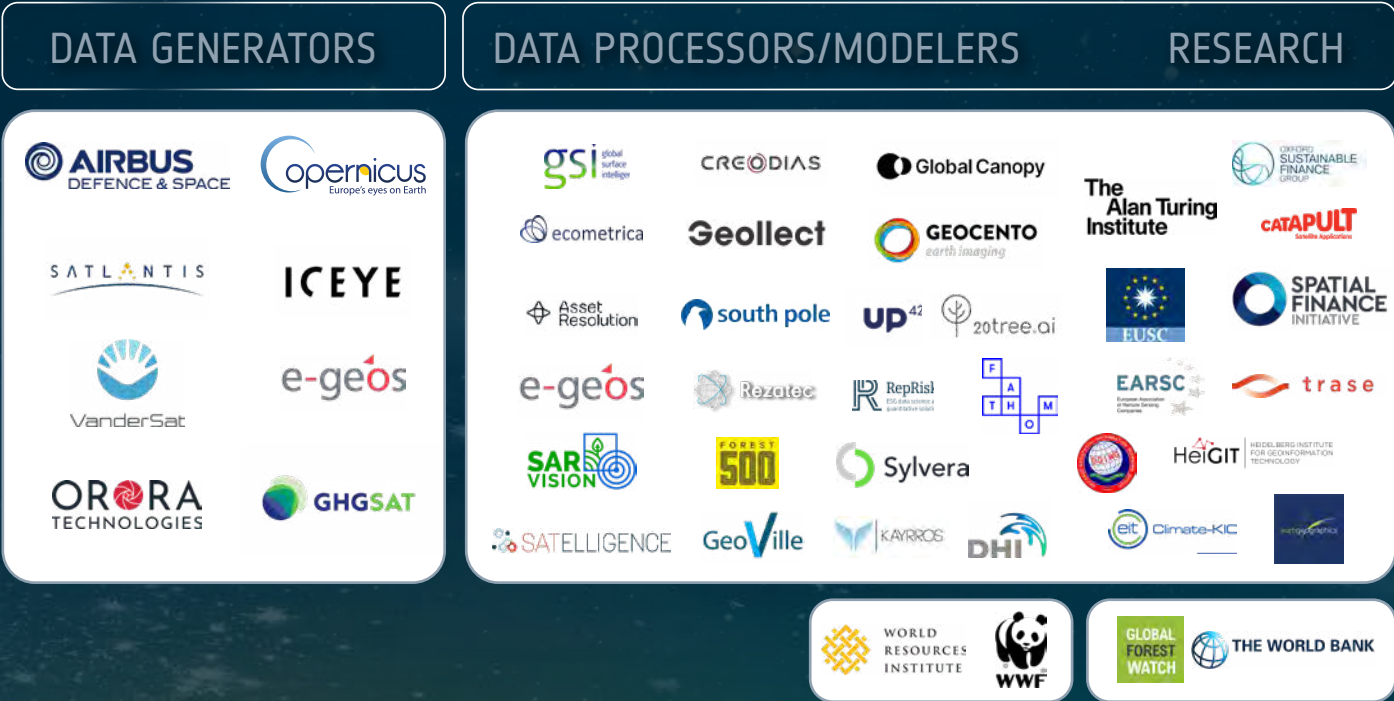


Figure 7: Examples of EO actors providing value to the Green Finance ecosystem.

16. See Space For Green Applications: CLIMATE RISK ANALYSIS FROM SPACE: REMOTE SENSING...

17. An early publication was already focusing on Green Growth projects as early as 2013 (Green Growth: Earth observation for international development projects): ENVIRONMENT, CLIMATE CHANGE AND GREEN...

18. Examples of use cases in the report: ADOPTION AND IMPACT OF...

19. See: THE WORLD BANK CURATES AND MAINTAINS A WIDE...

GHG observations have raised public awareness of the added value of satellites as exemplified by the RACE platform. For the time being, it is public satellites that generate the greatest added value for high-emission areas such as large cities, but the need for point source emission monitoring is gaining attention globally (e.g., large power stations, refineries or landfill) [24]. Considerable attention has also been given to Bluefield's, Kayrros' or GHGSat's²⁰ identification²¹ of methane leakages focusing on oil and gas and power plants. Yet, general stakeholders, including the finance industry, suffer from the lack of systematic asset-level GHG data collection, monitoring and verification. Remote sensing, together with local sensors, can help secure better data at higher frequency. With increasing sensor capabilities, computing power and machine learning, assets can be tagged and identified together with their characteristics [25]. Integration with existing IoT/in-situ sensors and systems and the related connectivity via satellite for data transmission can add value, especially in remote areas.

Asset-level emissions can be monitored directly or indirectly. Direct measurement by satellite is currently only feasible for a few use cases (in remote areas, for example) using commercial high-resolution payloads. Alternatively, asset characteristics identified through machine learning can

be used, which offers an indirect method for completing existing or building new data sets (in combination with accurate land use characterisation and change detection). Commercial high-resolution satellites are able to monitor, through direct measurements, asset-level emissions.

Sentinel-5P monitors methane (CH₄), formaldehyde (HCOH), aerosol, carbon monoxide (CO), nitrogen dioxide (NO₂) and sulphur dioxide (SO₂) in the atmosphere. Nevertheless, spatial resolutions of 7 km × 5.5 km or more are not sufficient for asset-level data (or only in remote areas). Hence, Sentinel-5P is currently providing a platform to guide commercial satellites, such as GHGSat satellites²², to pinpoint specific sources in higher resolutions. Figure 7 gives an overview of current and planned greenhouse gas monitoring missions.

The challenges outlined support the creation of new partnerships, especially Public Private Partnerships. The International Methane Emissions Observatory 2022 highlights the role of UNEP in helping oil and gas companies across the world measure and reduce their methane emissions. Another example is the partnership between the State of California, NASA and Michael Bloomberg, which launched the Carbon Mapper targeting large GHG emissions from individual sources²³.

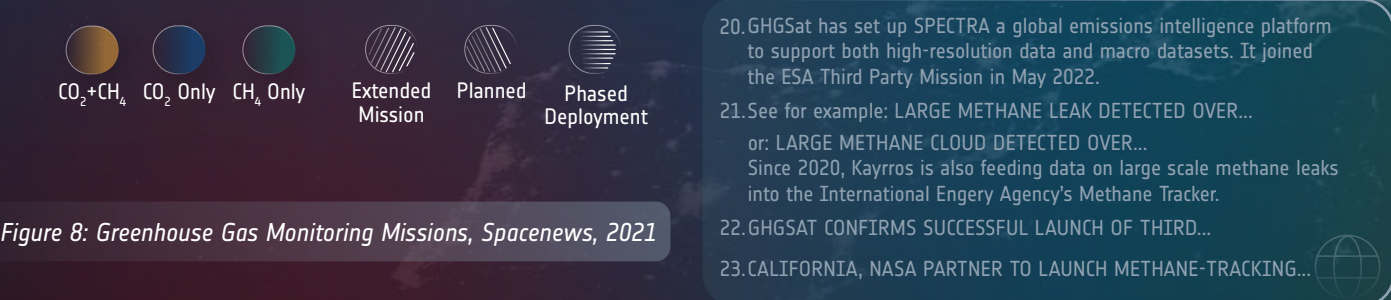
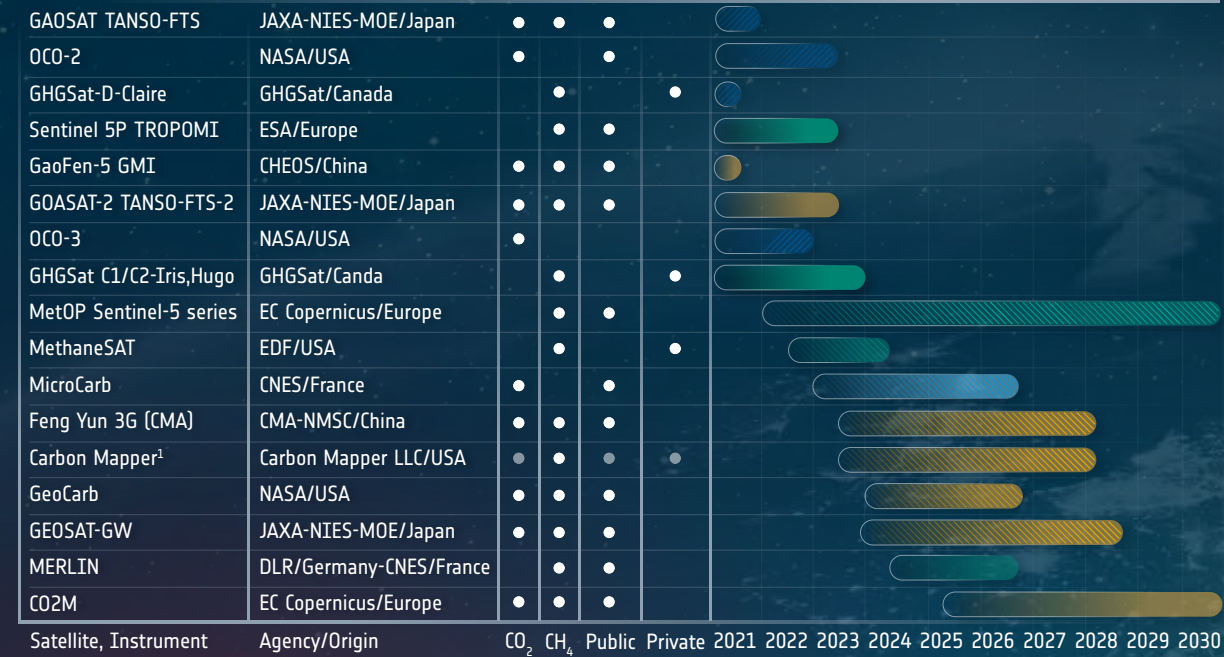


Figure 8: Greenhouse Gas Monitoring Missions, Spacenews, 2021

Data will be shared publicly, but companies that own and operate emitting infrastructure can pay to obtain access to the data sooner, allowing them to address leaks. Also, GHGSat and Shell formed a partnership to detect methane emissions in a year-long programme²⁴. More such partnerships can be expected to be formed in the future.

When it comes to **deforestation**, a number of space-based solutions have emerged. Major studies on deforestation such as the recent study by the World Resources Institute²⁵ built their analysis on various satellite-based data sources. ESA, together with the Committee for Earth Observation Satellites (CEOS), has supported initiatives such as the Carbon Tracking System, the Global Forest Observing Initiative and "Reduced Emissions from Deforestation and Forest Degradation" (REDD) activities. Successful pilot projects have, for example, integrated satellite data with other communication systems to set up local warning systems. Under increasing regulatory pressure, especially in commodity sectors, commercial, demand for such solutions will increase still further. European companies like Satellintelligence have developed services using Sentinel-1 and Sentinel-2 data, while Airbus and the Earthworm Foundation are offering a monitoring service called Starling to identify high-risk areas²⁶.

Presently, there is still a lack of clarity about standards associated with biodiversity loss, the sectors and industrial processes most affected, and the most appropriate approaches with which to measure biodiversity-related risks on behalf of the finance sector. Complementing costly on-the-ground measurements, the use of EO data to map and monitor biodiversity through alternative proxy insights

is a scalable and economical solution, as shown by the WWF and Maxar in the recent report "The Biodiversity Data Puzzle" [31]. The impact of an asset can be simplified into direct (habitat clearance) and indirect impacts. Also the Group on Earth Observations Biodiversity Observation Network (GEO BON) proposed a framework of essential biodiversity variables (EBVs) [27]. The United Nations Biodiversity Lab likewise uses spatial data for biodiversity. Further awareness-raising and needs identification are required in order to include insights into ongoing ESG-related biodiversity frameworks and regulations.

Satellites can set up baselines to identify new projects, but also to support the monitoring and reporting of the development and conservation of **nature-based solutions**, especially in the framework of climate adaption projects and carbon offset monitoring. Tech innovations are emerging to tackle the lack of monitoring such as the Global Mangrove Trust, Pachama, or the UK-based Sylvera (which so far has raised close to US\$40m), using various technologies, satellite data included among them. With the increase in carbon offsetting and related digital technologies including blockchain, new applications are beginning to emerge. Geospatial information is also key to obtaining natural wealth information on the country, not only project or regional level. This is relevant for national accounting, climate-related project selection and financial applications to climate funds, as well as sovereign debt. There is a need for long-term data sets to track changes in ecosystem services. Through the GDA programme, ESA is also supporting development banks in the development of remote sensed monitoring, reporting and verification (MRV) systems for land use emissions reduction programmes.

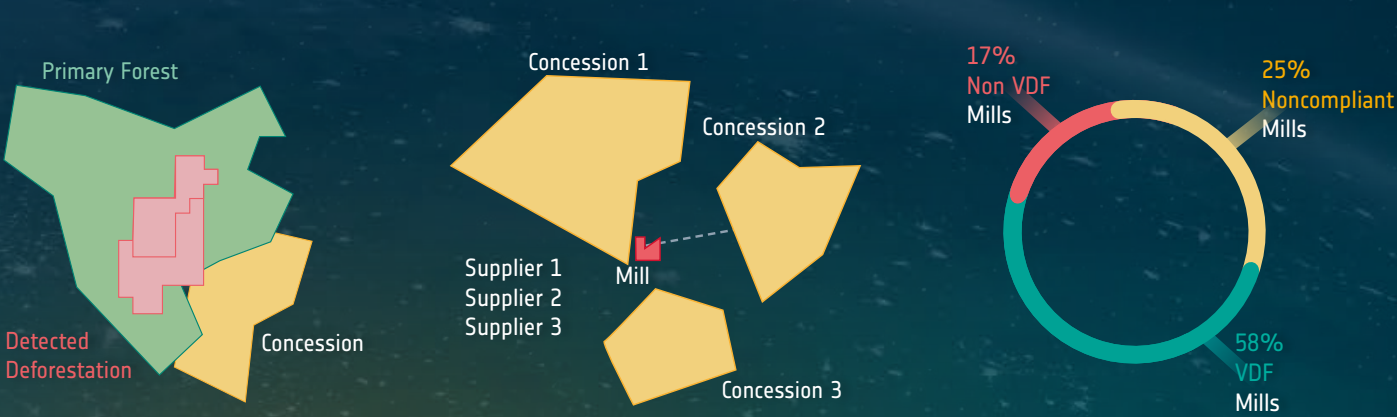


Figure 9: Satellintelligence provides services to prevent deforestation events, identify high risk sourcing areas, and measure progress and trends, Satellintelligence [27]

24. SHELL RECOGNISED FOR GOLD STANDARD METHANE...

25. Goldman, E., M.J. Weisse, N. Harris, and M. Schneider. 2020. "Estimating the Role of Seven Commodities in Agriculture-Linked Deforestation: Oil Palm, Soy, Cattle, Wood Fiber, Cocoa, Coffee, and Rubber." Technical Note. Washington, DC: World Resources Institute. Available online at: ESTIMATING THE ROLE OF SEVEN COMMODITIES IN AGRICULTURE...

26. STARLING...

Conclusion

A Green Finance Ecosystem is emerging and tighter regulations are driving commercial demand for ESG data, especially with regard to air pollution, deforestation and biodiversity. Data collection, monitoring and verification remains a challenge and approaches are currently dominated by indirect measurements and estimations. New policy measures and regulations across industries increase the need for worldwide, consistent, reliable and fact-based data. Corporates, investors and governments, therefore, require enabling data and tools in order to understand, plan and monitor risks at project, portfolio or even system level – as well as their impact on the environment.

In addition, with the likely relative shift from traditional Official Development Assistance projects to innovative climate financing, higher project volumes and more private stakeholders could be reached. Moreover, public actors,

from MDBs to national promotional banks, are pushing for increasing standards and green recovery with measurables results. On national level, further support opportunities might exist for the assessment of national natural wealth accounts, assessment of nationally determined contributions as well as related financing (sovereign and climate finance).

A systematic uptake of spatial data and solutions can be expected to occur driven by increasing interest from the financial community. In this context, ESA, with a considerable pipeline in supporting digital and green projects, can offer support to European companies and institutions worldwide. Programmes and activities such as InCubed, TIA Bass, FutureEO and Global Development Assistance are already leveraging space infrastructure to address the emerging green finance market.

Bibliography

- 1 "EUSPA EO and GNSS Market Report," 2022. [Online]. Available: https://www.euspa.europa.eu/sites/default/files/uploads/euspa_market_report_2022.pdf.
- 2 "Annual Impact Investor Survey 2020," 2020.
- 3 Bloomberg, "How Bloomberg is applying its data expertise to ESG," 2022. [Online]. Available: <https://www.bloomberg.com/professional/blog/how-bloomberg-is-applying-its-data-expertise-to-esg/>.
- 4 "Shell ordered to deepen carbon cuts in landmark Dutch climate case," Reuters , 2021. [Online]. Available: <https://www.reuters.com/business/sustainable-business/dutch-court-orders-shell-set-tougher-climate-targets-2021-05-26/>.
- 5 "Taskforce on Sclaing Voluntary Carbon Markets," 2021.
- 6 "Green bonds and carbon emissions: exploring the case for a rating system at the firm level," BIS, 2020.
- 7 IEA, "Methane Tracker 2021," 2021. [Online]. Available: <https://www.iea.org/reports/methane-tracker-2021>.
- 8 "FROM DATA TO ACTION: THE INTERNATIONAL METHANE EMISSIONS OBSERVATORY AS A CATALYST FOR GLOBAL METHANE EMISSIONS REDUCTION," 2021. [Online]. Available: <https://wedocs.unep.org/bitstream/handle/20.500.11822/36133/FDAG20.pdf>.
- 9 "State and Trends of Carbon Pricing 2021," International Bank for Reconstruction and Development / The World Bank, 2021.
- 10 E. M. W. N. H. a. M. S. Goldman, "Estimating the Role of Seven Commodities in Agriculture-Linked Deforestation: Oil Palm, Soy, Cattle, Wood Fiber, Cocoa, Coffee, and Rubber," World Resources Institute, 2020. [Online]. Available: wri.org/publication/estimating-the-role-of-sevencommodities-in-agriculture-linked-deforestation.
- 11 "Estimating the Role of Seven Commodities in Agriculture-Linked Deforestation: Oil Palm, Soy, Cattle, Wood Fiber, Cocoa, Coffee, and Rubber," WRI, 2020.
- 12 CDP, "THE COLLECTIVE EFFORT TO END DEFORESTATION," 2021.
- 13 "EU Communication (2019) on Stepping up EU Action to Protect and Restore the World's Forests," [Online]. Available: https://ec.europa.eu/environment/forests/eu_comm_2019.htm#:~:text=One%20of%20the%20commitments%20in,a%20forum%20to%20foster%20exchanges.
- 14 TNFD, "France's Article 29: biodiversity disclosure requirements sign of what's to come," 2021. [Online]. Available: <https://tnfd.info/news/frances-article-29-biodiversity-disclosure-requirements-sign-of-whats-to-come/>.
- 15 "Data voted the biggest hurdle for investors trying to address biodiversity," 2021. [Online]. Available: <https://www.responsible-investor.com/articles/data-voted-the-biggest-hurdle-for-investors-trying-to-address-biodiversity>.
- 16 "Finance and Biodiversity," Finance for Biodiversity Pledge, 2021.
- 17 "NGFS and INSPIRE launch a joint research project on 'Biodiversity and Financial Stability'," 2021. [Online]. Available: <https://www.ngfs.net/en/communique-de-presse/ngfs-and-inspire-launch-joint-research-project-biodiversity-and-financial-stability>.

18 "Biodiversity quickly rises up the ESG investing agenda," 2022. [Online]. Available: <https://www.ft.com/content/abbcec95-0154-40cd-83b9-d988bd3271b9>.

19 "State of Finance for Nature," UNEP , 2021.

20 "The Changing Wealth of Nations 2018 : Building a Sustainable Future," Worldbank , 2018.

21 "Making Peace With Nature," UN Environment Programme (UNEP) , 2021 .

22 "Sustainability and Satellites: New frontiers in sovereign debt investing," 2019.

23 "Spatial Finance: Challenges and Opportunites in a Changing World," WB / WWF , 2020.

24 N. Publications, Progress report on bridging data gaps, 2021.

25 State and Trends of Spatial Finance 2021", Spatial Finance Initiative, 2021

26 "Route to Market report," Catapult , 2018.

27 "Climate risk analysis from space: remote sensing, machine learning, and the future of measuring climate-related risk," University of Oxford , 2018.

28 Spacenews, "Space and the Business of Climate Change," 2021

29 Satelligence, 2022. [Online]. Available: <https://satelligence.com/deforestation>.

30 "https://www.wwf.org.uk/sites/default/files/2022-12/The-Biodiversity-Data-Puzzle.pdf," Maxar Technologies , 2022.

31 S. Andrew, "Priority list of biodiversity metrics to observe from space," 2021.

32 "Assessing Physical Risks from Climate Change: Do Companies and Financial Organizations Have Sufficient Guidance?," WRI, 2021.

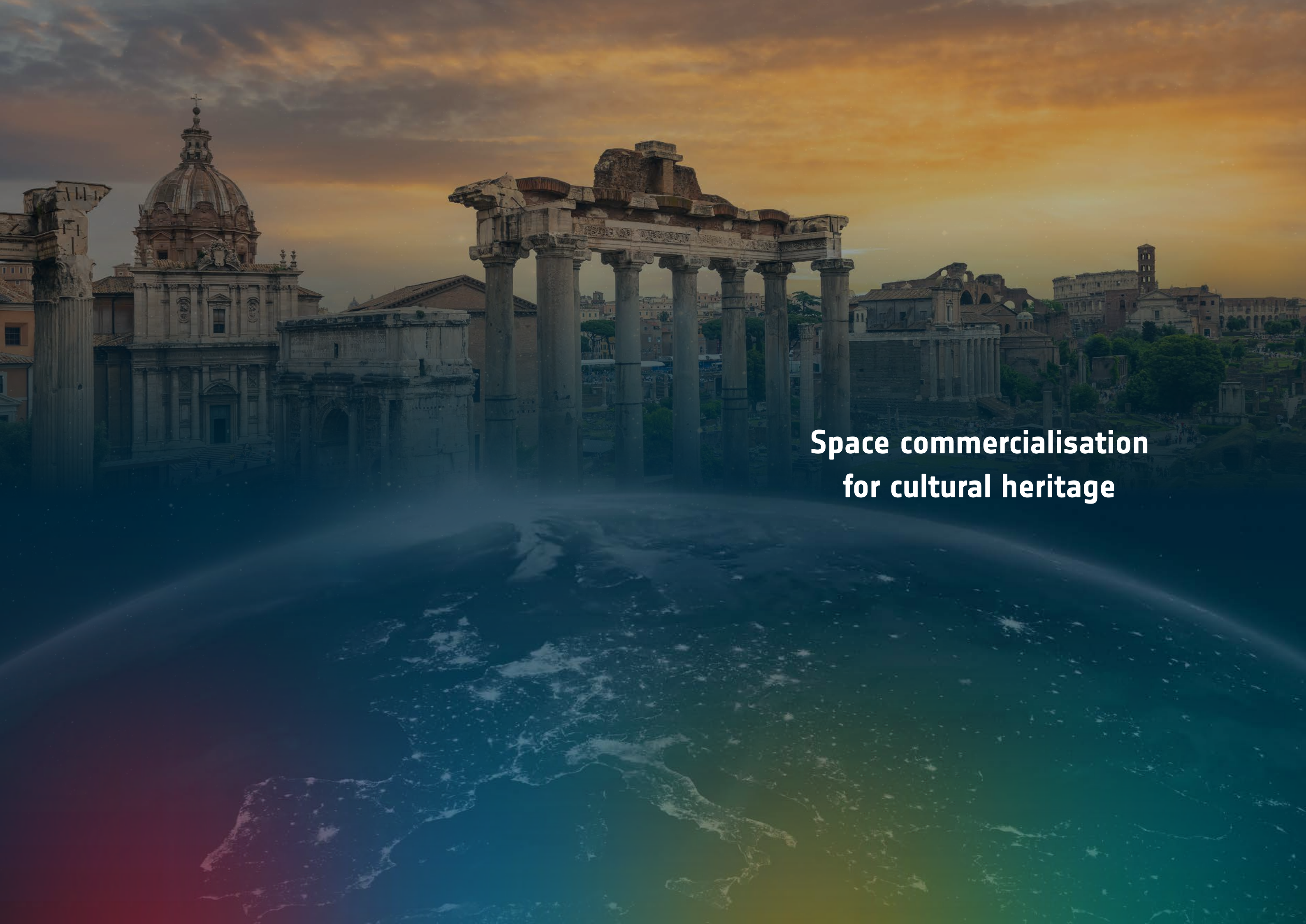
33 "Climate-related risks to financial stability," ECB, 2021.

34 G. S. I. Alliance, Global Sustainable Investment Review, 2018.

35 United Nations Environment Programme Finance Initiative, "Charting a New Climate," 2020.

ACRONYMS

CDP	Carbon Disclosure Project
CFA	Chartered Financial Analyst
CO	Carbon monoxide
EBV	Essential biodiversity variables
ESG	Environmental, Social and Governance
ESA	European Space Agency
ETS	Emissions Trading System
EU	European Union
FI	Financial Institution
GEO BON	Group on Earth Observations Biodiversity Observation Network
GHG	Greenhouse Gases
HCOH	Formaldehyde
IOT	Internet of Things
IPCC	Intergovernmental Panel on Climate Change
ISIN	International Securities Identification Number
LEI	Legal Entity Identifier
MDB	Multilateral Development Bank
NGFS	Network for Greening the Financial System
NO2	Nitrogen dioxide
PACTA	Paris Agreement Capital Transition Assessment
PPP	Public Private Partnership
SDG	Sustainable Development Goals
SFDR	Sustainable Finance Disclosure Regulations
TCFD	Task Force on Climate-related Financial Disclosures
SO2	Sulphur Dioxide
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
WB	World Bank
WRI	World Resources Institute
WWF	World Wide Fund For Nature



**Space commercialisation
for cultural heritage**

Space commercialisation for cultural heritage

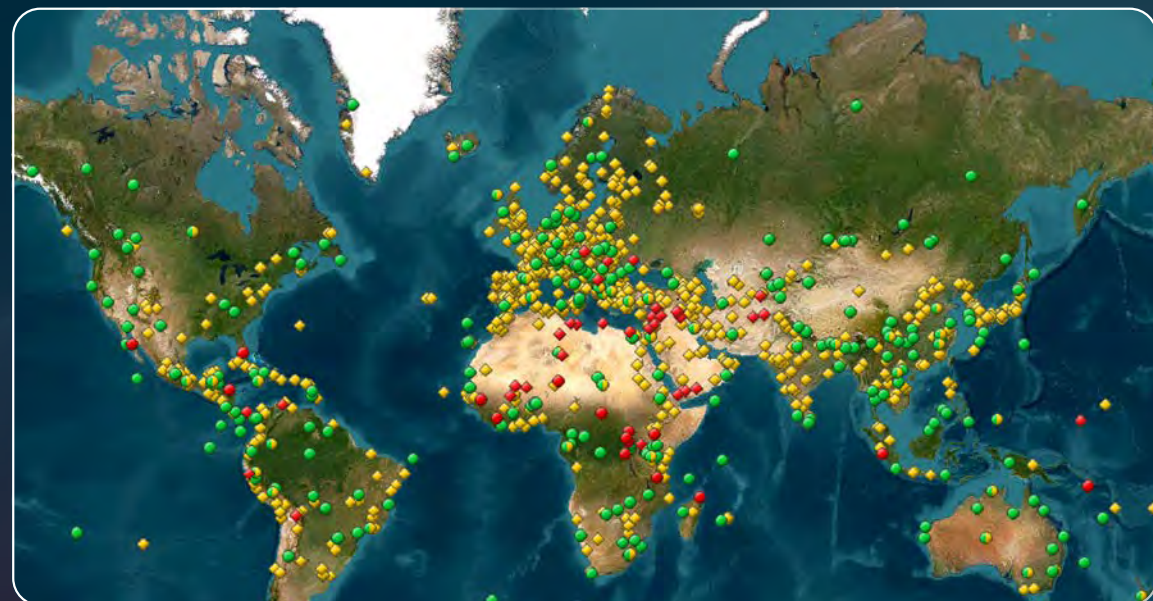
Overview of Cultural Heritage ecosystem and value chain

Cultural Heritage is gaining attention, notably from the public sector, which provides the largest part of funding, but also from the private sector, that is trying to seize the associated growing commercial opportunities. Indeed, in the last decades, in addition to the historic, social and anthropological dimension, Cultural Heritage has also become a major driver for economic growth and sustainable development by attracting tourists which in turn boosts the economies of the destinations visited. In Europe, it is estimated that cultural tourism accounts for 40% of all tourism¹. This creates employment: when it comes specifically to Cultural Heritage, around 300,000 Europeans work directly in this sector².

BUT WHAT EXACTLY IS CULTURAL HERITAGE?

Today there are 1,157 sites on UNESCO's World Heritage list³, 900 of which are cultural sites and 39 of which are mixed sites (both cultural and natural). Among the 900 cultural sites, 39 are considered in danger.

By assigning places as Cultural Heritage Sites for already a half century, UNESCO has helped to pass them on to future generations by encouraging commitment to Cultural Heritage conservation. This includes providing emergency assistance for sites in danger, offering technical assistance and professional training, and supporting public awareness-building activities. But Culture Heritage is of course more than Cultural Heritage sites. The meaning of Cultural Heritage has expanded over time from single objects to historic cities, cultural landscapes, and serial properties.



UNESCO's map of World Heritage sites

1. CULTURAL TOURISM...
2. EU POLICY FOR CULTURAL HERITAGE...
3. WORLD HERITAGE LIST...



Because of its very important socio-economic impact, Cultural Heritage is now addressed by a large variety of actors at various levels: international organisations, the European Commission, national governments, regions, site managers, etc.

Main Cultural Heritage international stakeholders

	The United Nations Educational, Scientific and Cultural Organization		CIPA Heritage Documentation
	The International Centre on Space Technologies for Natural and Cultural Heritage		The International Centre for the Study of the Preservation and Restoration of Cultural Property
	The Digital Heritage Research Lab		The International Union for Conservation of Nature
	The International Council on Monuments		The United Nations Institute for Training and Research
	The International Council of Museums		The International Criminal Court

They are providing support across the Cultural Heritage value chain:

Value chain

Prospection & Exploration

This segment integrates all the prospection activities linked to the discovery and the study of a site by sector professionals and national, regional, and local authorities in view of its formal recognition as a Cultural Heritage site.

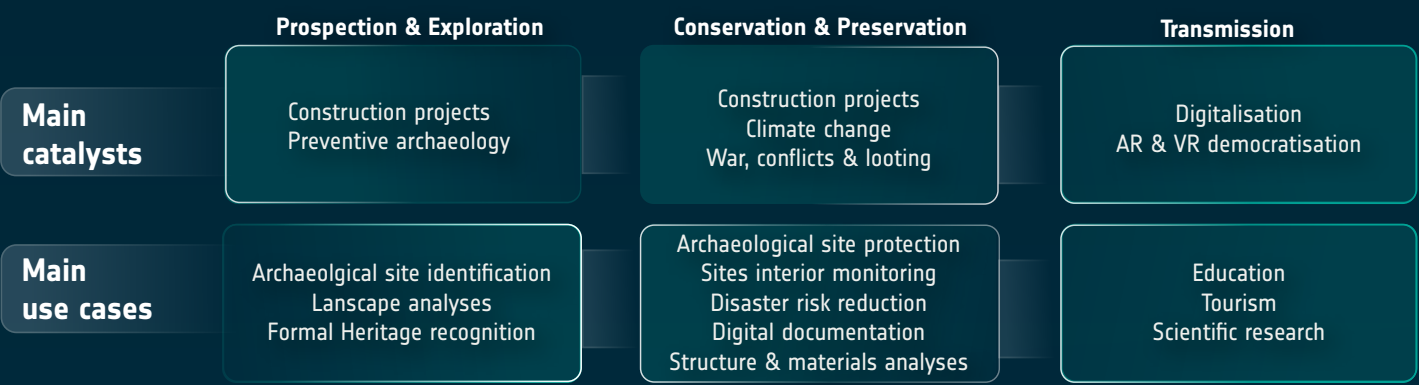
Conservation & Preservation

This segment integrates all activities linked to the monitoring of a site and its protection by sector professionals, natural sciences experts as well as site operators and local authorities.

Transmission

This segment integrates all activities enabling to provide public with access to Cultural Heritage for touristic, educational, or scientific purposes: site management, knowledge collection for research, valorisation through commercial products development.

Main Cultural Heritage needs and space added value



As highlighted during a dedicated one-day workshop organised by the European Space Agency's (ESA) Commercialisation Gateway⁴, space-based solutions address emerging needs across the whole Cultural Heritage value-chain:

PROSPECTION & EXPLORATION:

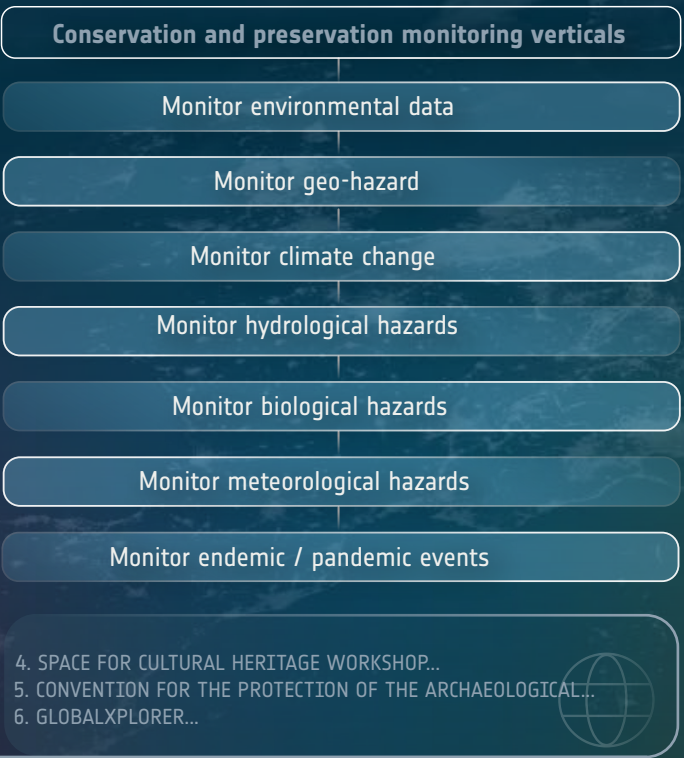
Archaeological research, traditionally mainly funded by governmental and philanthropic sources, has grown exponentially in the last two decades with new research units, but also emerging private sector companies. The sector is facing increasing demands to become more results-driven and cost-effective, in times where activities such as site surveying have considerably increased in costs in Europe but also in emerging countries. Moreover, as reflected by the Valetta Convention⁵ adopted in 1992, construction projects have emphasised the importance of development-led, rescue and preventive archaeology, driving new commercial opportunities for space-based solutions.

Today, in Europe, prospection and exploration activities are mainly carried through on-site inspections, in person or by drones, or commissioned aerial photography inspections. LiDAR has also long been viewed as the 'gold standard'. However, these in-situ approaches are both labour and time intensive, but also expensive and inappropriate for large, dangerous, and hard to access areas. This is changing thanks to Earth Observation methods that are increasingly finding their way into mainstream archaeology and enable to cover large, previously inaccessible areas effectively and precisely. Since the 1980s, the use of Synthetic-aperture radar (SAR) data has for example been explored to identify buried archaeological features in dry desert areas. Currently, a rising interest has been seen in the use of Earth Observation (EO) for prospection of marine, coastal and fresh water archaeological sites. To process and analyse space derived data, the use of experts' team is well established. In addition, new approaches such as crowdsourcing or automated site detection and change detection based on Artificial Intelligence (AI) are also gaining ground. Crowdsourcing is notably carried by the

GlobalXplorer⁶ online platform that uses the power of the crowd to analyse satellite images currently available to archaeologists.

CONSERVATION & PRESERVATION:

Cultural Heritage sites are in danger. Climate change (especially changes in temperature, precipitation, and atmospheric moisture), that is already having negative impacts on 34% of natural World Heritage sites, has become the number one threat to them. Moreover, Cultural Heritage is also facing many more human-induced threats (war and conflicts, exploitation of resources, pollution, overtourism, etc.) as well as geo-hazards, land change or ground movements, etc. Urgent safeguarding measures therefore must be deployed to mitigate their impact. This includes the surveillance and modelling of the evolution of the natural environment surrounding Cultural Heritage sites based on a very diverse range of monitoring verticals:



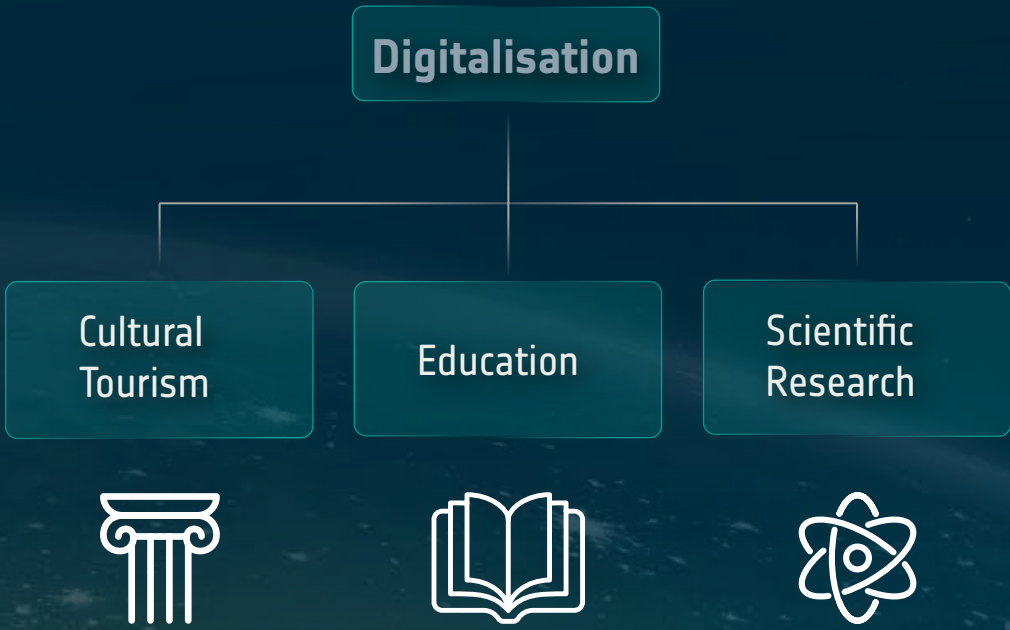
All these verticals can benefit from the use of EO data, models, dedicated monitoring of changes and connectivity. These can be used to understand changing site surroundings at scale and in a systematic manner, automate the identification of criticalities or deformations affecting structures, secure rapid emergency interventions, etc. Global Navigation Satellites System (GNSS) data moreover brings another essential layer of information, for example to precisely map ground deformation or access visitors' positioning for flow analysis.

TRANSMISSION:

Knowledge about Cultural Heritage is not equally accessible to everyone, in particular not to the youngest generations, and should therefore be improved. Cultural tourism as well as Cultural Heritage education and scientific research are all heavily disrupted by the development of new digital technologies: developments in 3D-capturing, 3D-processing, and multimedia tools such as augmented reality or virtual reality are some examples expected to increase in

adoption. Covid-19 has accelerated this digitalisation of Cultural Heritage in times of limited possibilities of visiting physical visits.

Digitalisation however raises the question on how to best capture, document, store, preserve and provide 3D data effectively to the Cultural Heritage community. If capture is currently mainly done through methods such as photogrammetric acquisition, mobile scanning, UAV-flying, ground/aerial survey and LiDAR, there is a growing interest to use raw satellite data (e.g. SAR) to support the development of 3D surface models of Heritage sites. Space also has a role to play in this through GNSS which can trigger information based on the visitor's position on the Heritage site. The emergence of future generation mobile network 5/6G will also bring these immersive technologies to the next level by offering enhanced computing power and thus improving user experience and furthering the potential for mass adoption. Satellite communications could potentially support the enablement of these services for sites where there is insufficient terrestrial coverage.



➔ To unveil, safeguard and capitalise on Cultural Heritage, decision makers need data: this is where the space sector, combined with cutting edge technologies such as Artificial Intelligence and machine learning, can play an important role.

Space-added value by public initiatives

As attention to Cultural Heritage management is still very much driven by the public actors, so is the use of satellite remote sensing data in the sector. On the European level, UNESCO and ESA have long been working for the integration of both fields, notably through the joined launch of the "Open Initiative on the Use of Space Technologies to Support the World Heritage Convention"⁷ in 2003. Since then, ESA has been developing various projects across the whole Cultural Heritage management value chain:

The Copernicus Programme is also a key lever for applying space to Cultural Heritage use-cases. A dedicated study called "Copernicus services in support to Cultural Heritage"⁸ has been carried out in 2018, assessing the possibility of initiating institutional actions for the promotion of Copernicus data for Cultural Heritage preservation, monitoring and management. The study highlighted that the different Copernicus core services have already

internally the relevant products to cover partially and entirely 16.5% of the user requirements expressed by the Cultural Heritage user communities over the value chain. This percentage moreover increases when considering Sentinels capabilities and Copernicus Contributing missions. Nevertheless, as of today, Cultural Heritage is not directly mentioned in any delegation agreement of the Copernicus core services' entrusted entities, thus not encouraging the development of specific products or adaptation of existing ones to respond to Cultural Heritage-associated needs.

Finally, on the national or local levels, many initiatives are flourishing. As an example, the Research Centre of the Slovenian Academy of Sciences and Arts (RCSAS) is developing a tool for visualising LiDAR data in the context of the Cultural Heritage sector that is expected to make EO data and AI methods more accessible to the Cultural Heritage community.

Example of ESA projects

PROSPECTION & EXPLORATION

ArchEO

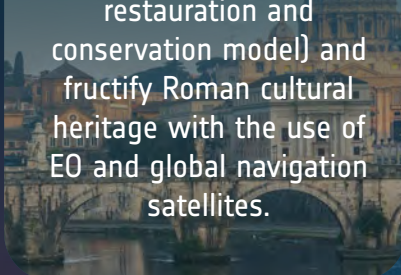
The **Archaeological** application of **Earth Observation** Techniques project aims to identify favourable conditions favourable for the analysis of archaeological sites and landscapes in Central Europe with the use of satellite-based optical data.



CONSERVATION & PRESERVATION

AMOR

The **Advanced Multimedia and Observation** services for the **Rome** cultural heritage ecosystem project aims to safeguard (through a predictive restauration and conservation model) and fructify Roman cultural heritage with the use of EO and global navigation satellites.



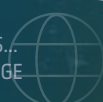
TRANSMISSION

INVENTA

The **IN**novative serVices to **EN**hance the valorization, promotion and the preservation of culTural heritAge project aims to valorise Cultural Heritage with the use of Virtual and Augmented Reality combined with the 5G network Satellite Navigation and Earth Observation space technology.



7. SPACE TECHNOLOGIES FOR HERITAGE: TWO CASE STUDIES...
8. COPERNICUS SERVICES IN SUPPORT TO CULTURAL HERITAGE



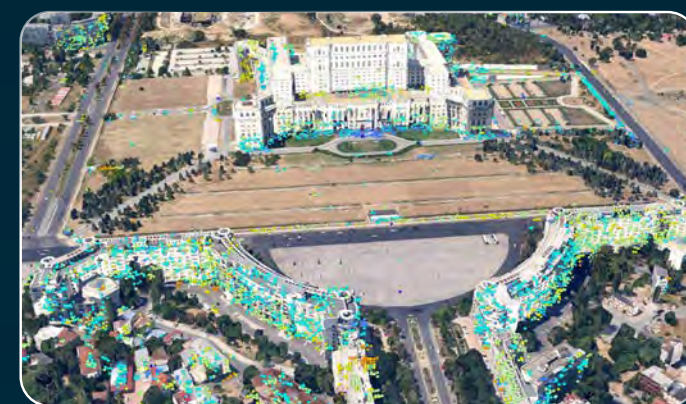
Space-added value by commercial initiatives

In the field of prospection & exploration, private sector companies have emerged. Among these, ArchAI⁹ is the first company proposing a platform that leverages EO, AI and computer vision models to automate Heritage feature detection. It joined ESA BIC UK in 2021 to focus on the development of its second product to de-risk the construction industry by automatically detecting archaeological sites.



Images of the Isle of Arran in Scotland with predictions showing all the different site types that ArchAI has trained their Artificial Intelligence on

In the field of Conservation and Preservation, the need to monitor and record a large panel of data linked to climate change has been highlighted, as well as geo or hydro-hazards, tourism flow, etc. As per the diversified nature of data types to monitor and associated data collection methods, there is a great need to centralise this information in easy to access structured information platforms. Although not only specialised on Cultural Heritage use-cases, many EO companies do so by proposing platforms for critical infrastructure monitoring, environmental risk analysis, emergency planning, etc. The Romanian based company Terrasigna¹⁰ for example provides ground deformation and infrastructure stability risk analysis services mainly based on Synthetic Aperture Radar Interferometry (InSAR) and Persistent Scatterer Interferometry (PSI). The Romanian Palace of Parliament, one of the largest buildings in the world and a major tourist attraction, was notably subject to such a risk evaluation¹¹.



Satellite radar scans show various points on and around the Palace that are slightly rising in blue or sinking in yellow/orange [source: Terrasigna]

In the field of transmission, the global augmented and virtual reality market size was valued at \$27.6 billion in 2021 and is projected to reach \$856.2 billion by 2031. However, the adoption rate under Cultural Heritage sites is still low due the current price point. This has also partially to do with the fact that the sector is reliant on public funding which in some cases can limit the investments in these types of technologies. Some companies working on Cultural Heritage use-cases nevertheless foster digitalisation of the sector and are showing interest in the possibilities offered by space. This is the case of Mindesk, in which the CEO took part in the dedicated one-day workshop organised by the European Space Agency (ESA) Commercialisation Gateway¹². The company that offers expertise to effectively present and review infrastructure projects in Virtual Reality, believes satellite data is fundamental for feeding 3D models for exploration and learning at different local, regional, and global scales.

→ ESA can support European companies willing to bridge the gap between space and Cultural Heritage through many initiatives such as the InCubed Programme¹³, the ESA BIC network¹⁴, TIA BASS¹⁵, the Destination Earth programme¹⁶, and much more.

9. ArchAI...
10. NATIONAL GROUND MOTION MONITORING: ROMANIA...
11. ROMANIAN PARLIAMENT PALACE - RISK ASSESSMENT
12. SPACE FOR CULTURAL HERITAGE WORKSHOP...
13. INCUBED IS AN ESA PROGRAMME MANAGED...
14. ESA BUSINESS INCUBATION CENTRES...
15. TIA BASS...
16. DESTINATION EARTH...





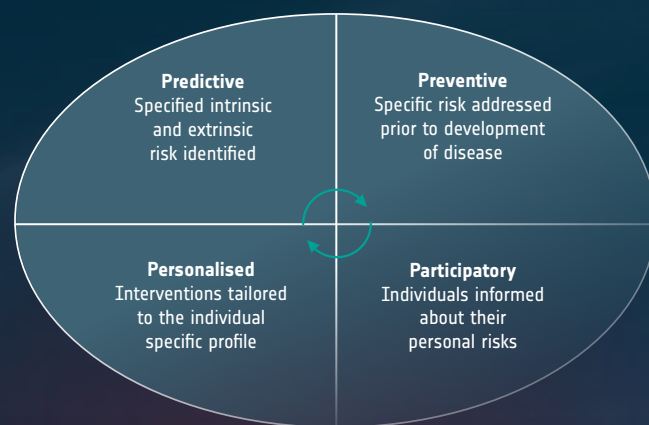
Space commercialisation for healthcare

Space commercialisation for healthcare

Critical healthcare challenges in Europe

Healthcare in Europe has long been considered as one of the best in the world due to a number of social economic factors (access to housing, food, care, medical education, advanced medical research, etc.) and has been overall continuously improving. At the same time, many challenges for Europe must still be addressed, including an **ageing population**, a **greater prevalence of chronic diseases** and the emergence of tropical diseases (due to climate change) which are intensifying demand for services and threatening the sustainability of European healthcare systems¹. The COVID-19 crisis has laid bare the need to tackle **workforce shortages** and strengthen the resilience of the healthcare system, (including products and chemicals sourcing), as well as highlighting the **growing pace of digitalisation**.

Moreover, an analysis of EU health systems highlights the need for a shift towards **prevention, primary care and integrated care**². The 2019 Companion Report from the European Commission reaffirmed the need to prioritise health promotion as a prerequisite to achieving effective and resilient health systems³. Today, healthcare resources are mainly targeted to people in acute phase of sickness but prevention, as a share of total health spending, represents just over 3% on average.



Issues linked to an **ageing workforce**, **recruitment and employee retention** as well as an **uneven geographical distribution** between and within in EU regions also need to be addressed. Problems also exist with **timely access** to certain services, leaving many people and especially those with mental health problems, disabled persons, older persons, and people in need of palliative care particularly disadvantaged.

Finally, the digitalisation of the European healthcare sector is extremely patchy. Research carried out by the Bertelsmann Stiftung compared 14 EU member states and 3 OECD countries, showing that countries are digitalising their healthcare systems at very different speeds⁵. Estonia and Denmark, where all citizens can view their test results, medication plans or vaccination data online, rank at the top of the index, whereas France, Germany and Poland are trailing behind. Moreover, while myriad innovative solutions are being developed, it is their coordination, their integration in digital platforms, the user experience they offer, and above all, the associated reimbursement scheme that will determine their potential for commercialisation⁶. In other words, health innovation, if it is to take hold, is dependent on being integrated with regulatory ecosystems at national and supra-national level.

An overview of the regulatory health ecosystem in the EU
In the European Union (EU), healthcare is currently governed by national regulations with no unified legal framework established for its provision in the EU. Regulatory fragmentation has led to legal complexity in areas such as GDPR, reimbursement rules, medical guidelines and clinical trials. This legal complexity is slowing down the development of telemedicine and eHealth solutions. At EU level, **DG SANTE**, **DG CONNECT** and **DG RTD** are directly and indirectly responsible for health-related topics. Recently, EU agencies also stepped in, with the **European Centre for Disease Prevention and Control (ECDC)** and the European Medicines Agency (EMA) playing a key supportive role in the response to the COVID-19 pandemic⁷. The new **EU4Health 2021-2027** programme⁸ aims to counter the negative impacts of COVID-19 by investing in prevention, crisis preparedness, the procurement of medicines and equipment, and improving long-term health outcomes. The Commission also proposed the creation of a **European Health Data Space**⁹ in 2021 to strengthen the EU's crisis preparedness and response, taking the first steps towards a European Health Union.

This report highlights some of the numerous examples of synergies between the space and the healthcare sectors.

1. STRENGTHENING EUROPEAN HEALTH SYSTEMS (EFPIA.EU)...
2. POLICY BRIEF_A4 (EHMA.ORG)...
3. 2019_COMPANION_EN_0.PDF (EUROPA.EU)...
4. 2019_COMPANION_EN_0.PDF (EUROPA.EU)...
5. BERTELSMANN COMPARES DIGITAL STRATEGIES...
6. THE EUROPEAN PATH TO REIMBURSEMENT FOR DIGITAL...
7. EMA'S GOVERNANCE DURING COVID-19 PANDEMIC...
8. PROGRAMME L'UE POUR LA SANTÉ 2021-2027...
9. EUROPEAN HEALTH DATA SPACE (EUROPA.EU)...



Space-added value

Emerging technologies and new business models are creating a market pull for new solutions in areas where space can potentially add significant value. These areas include:

- **Medical and biomedical research** including tissue engineering, personalised medicine, drug development and disease modelling;
- **Telemedicine and digital health** for healthcare prevention, remote diagnosis, patient treatment and monitoring, digital health applications and connectivity;
- **Public health management** for environmental health, health at individual, group, population or ecosystem level and hospital delivery care operations.

The European Space Agency (ESA) has been active in the field of healthcare for many years and has supported several types of activities, from technology development to commercialisation. The **Earth Observation Directorate** has for example been very

active in the field of epidemiology, while the **Directorate of Technology, Engineering and Quality**, hands in hands with the **Technology Transfer Programme Office**, paved the way for many technological innovations. Through numerous projects¹⁰, and through the **Business Incubation Network**¹¹, ESA has furthermore already supported over 70 start-ups located at the intersection of space and health in a variety of areas such as cancer treatment, sustainable food or personalised nutrition for space travel. The **ESA Business Applications and Space Solutions programme** (ESA BASS) has notably successfully implemented a number of projects and build partnerships with key stakeholders such as the UK National Health Service (NHS). Moreover, the **ESA Technology Transfer Office**¹² supports technological exchange between the space and health sectors with spin-ins, as well as spin-offs. In addition, the **Business in Space Growth Network**¹³ (BSGN), notably through its Life Sciences Industry Accelerator¹⁴, offers opportunities for pharmaceuticals and biomanufacturing industrial research by facilitating access to commercial space-based platforms in Low Earth Orbit.

Medical and Biomedical Research



The space industry can be leveraged by the healthcare industry as a platform for testing and manufacturing.

The effects of microgravity on biological, chemical and physical processes which can be observed in space-based laboratories enhance our understanding of a broad range of diseases, making it possible for the public and private sectors to improve existing treatments as well as develop new medicines for humans on Earth. The possibilities include, but are not limited to, 3D tissue cultures, tissue regeneration, DNA regulation, drug and vaccine development, stem cells, bone physiology and pathology, and treatments for diseases such as cancer and other life-threatening and debilitating conditions. In particular, the formation of protein

crystals is key to the pharmaceutical industry which uses crystal dissolution to deliver medications in the fight against a broad range of protein aggregation-related diseases¹⁵ (Alzheimer's, diabetes, Parkinson's, etc.). Moreover, microgravity-induced osteoporotic modelling (accelerated bone loss in microgravity) can be of great assistance in the testing of bone-like structures. Further revenue-generating applications can be found in drug design, structural biology and bioseparation. The effects on human physiology of microgravity combined with isolation and harsh environments can also improve our understanding of changes in metabolism and nutrition, cardiovascular regulation and respiration, immunology, psychological fitness and ageing¹⁶.

Added value of space for healthcare testing and manufacturing

ORBITAL & SUBORBITAL COMMERCIAL RESEARCH

Orbital and suborbital testing aboard the ISS or other orbital facilities can advance medical research

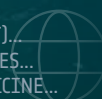
GROUND-BASED COMMERCIAL RESEARCH

The space industry has developed ground-based facilities for research that can simulate space conditions (e.g. Yuri Gravity Clinostat) and serve to de-risk the hardware or fine-tune experiment protocols

IN-ORBIT MANUFACTURING

The space environment is of interest for biomanufacturing of life sciences products and technologies (tissue engineering, organ on a chip) and the manufacturing of materials (thin film technology) which may be of interest for med tech in the long term

10. ESA - PAST FUNDED PROJECTS (HEALTH, MEDICINE & PHARMA)...
11. ESA BUSINESS INCUBATION CENTRES...
12. ESA - ESA'S TECHNOLOGY TRANSFER AND PATENT OFFICE...
13. THE BUSINESS IN SPACE GROWTH NETWORK (ESA.INT)...
14. LIFE SCIENCES INDUSTRY ACCELERATOR - BSGN (ESA.INT)...
15. SPACE AND HEALTH: A LONG SUCCESS STORY OF SYNERGIES...
16. (PDF) SPACE MEDICINE PROPELLING EARTH-BASED MEDICINE...



In Europe, commercial services like the ICE Cubes Service and Bioreactor Express Service are facilitating access to the European Columbus Laboratory aboard the International Space Station (ISS) where commercial microgravity research can be carried out by paying customers. Several start-ups and SMEs that focus on the development of related experiment hard- and software are specialized in and working for pharmaceutical and biomedical industry, for example Space Pharma and Yuri Microgravity. ESA's BSGN has signed a Memorandum of Understanding with the ESA's BSGN has signed a Memorandum of Understanding with the Exploration Company to assess the potential of the Nyx capsule to deliver payloads to Low Earth Orbit¹⁷. ESA's Boost Programme¹⁸ is supporting Space Forge with the development of a satellite-based microgravity research and production facility¹⁹. Furthermore, through the Commercial Applications enabled by Space Environments (CASE) Open Call for Proposals, ESA supports the development of commercial services that benefit from microgravity and space environments.

ESA's Space Rider²⁰ will further increase European capabilities in this market by providing access to regular uncrewed deliver of payloads to Low Earth Orbit.

Various biotech start-ups have already had the chance to carry out research in microgravity conditions²¹. In March 2023, the fourth commercial Kirara project was for example launched to space. It is currently hosted inside the Facility of the ICE Cubes Service²² on the International Space Station (ISS) by Space Applications Services²³. However, low awareness among further potential clients remains a barrier, as are misconceptions in terms of the time, cost and value proposition of space-based research. What is needed is a holistic approach, with collaboration stimulated further among institutions, research organisations and private players, including investors, within the health sciences industry, as well as with space service providers.

BSGN partners (source: BSGN)



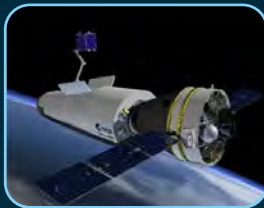
BARTOLOMEO



ICE CUBES SERVICE



YURI MICROGRAVITY



SPACE RIDER



BIOREACTOR EXPRESS SERVICE



LUNAR PATHFINDER



GOONHILLY DEEP SPACE COMMUNICATION



ESA MATERIALS & ELECTRICAL COMPONENTS LABORATORY



SPACE PHARMA



SPACE FORGE



NYX | THE EXPLORATION COMPANY



LSAS - LUNAR SURFACE ACCESS SERVICE BY OHB



LUNAR TRANSPORTATION AND EXPLORATION SERVICES BY ISPACE

17. <https://bsgn.esa.int/2022/12/12/private...>
18. ESA - BOOST!
19. https://www.esa.int/enabling_support/space...
20. SPACE RIDER - BSGN (ESA.INT)...
21. [https://bsgn.esa.int/2022/09/21/95933-revision-v1/...](https://bsgn.esa.int/2022/09/21/95933-revision-v1/)
22. ICE CUBES SERVICE - BSGN (ESA.INT)...
23. SPACE APPLICATIONS...



Telemedicine and Digital health



The digital transformation is playing an increasingly vital role in the healthcare sector: by 2025, Roland Berger estimates that the share of digital products and services in the total healthcare market will grow to 12%, or nearly €1tn, with Europe alone accounting for around €232bn. Much of this surge in digitalisation results from the tremendous progress made in a variety of fields including robotics, **augmented reality** and **3D printing**, and the **connected devices** such as sensors, applications, wearables and other mobile gadgets that use these enabling technologies to deliver e-health services. The health-related data collected by these devices can then be saved in platform-connected **data hubs** for analysis by **artificial intelligence** (AI) or machine learning (ML) algorithms.

Innovation in the health sector is to a large extent driven by start-ups specialising in clinical intelligence, real-world evidence, virtual care delivery, drug discovery, disease management, the pharma supply chain, and more. Drug companies have established venture capital funds and incubators to invest in promising start-ups working on new drug technologies and are hence outsourcing development risks²⁴. But innovation it is also being fostered by tech giants as digital pioneers breaking into the healthcare market, with, for example, Amazon's diversification into the health insurance and online pharmacy²⁵ segments.

The telemedicine market in Europe is estimated to grow from \$11.32bn in 2022 to \$21.80bn by 2027²⁶. A study by Accenture has indicated that, globally, 40% of patient visits could be performed remotely by 2030²⁷.

In addition to telemedicine becoming more widely accessible, another main driving force behind the uptake of innovative healthcare solutions is the growing volume of healthcare data. The use of digital technologies in the form of mobile phones, fitness trackers, heart rate monitors, online health coaches, wearables and sensors has become commonplace, and more than 300,000 health-related applications are available for use on mobile phones. Leading companies such as Phillips Healthcare and Medtronic, as well as newly arrived start-ups and SMEs, offer a wide portfolio of **remote patient monitoring** (RPM) services. ESA, through its incubation programme²⁸, has supported companies such as Portables HealthCare Technologies²⁹, which has developed a wearable sensor system that analyses gait and transfers data wirelessly to a data hub.

Healthcare digitalisation technological layers



IoT & Connectivity (5G)

Augmented reality, robotics, 3D printing, new sensors, applications, wearables, lab-on-chip technologies

Data hubs, cubs and platforms

Artificial intelligence

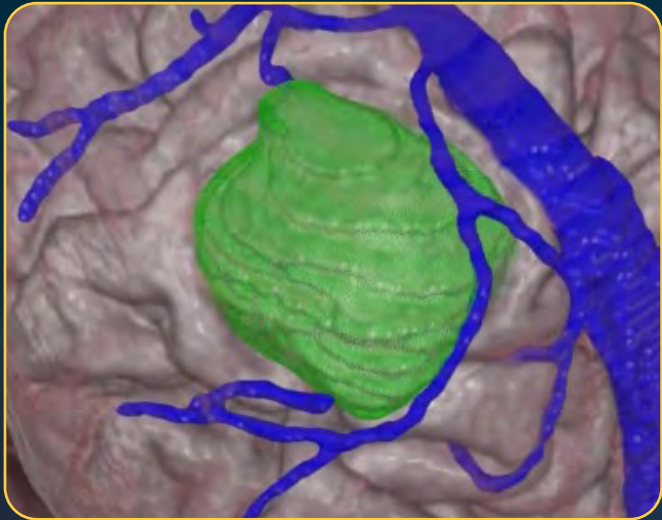
24. BIG PHARMA IS USING ITS VENTURE CASH...
25. AMAZON LAUNCHES \$5-A-MONTH UNLIMITED...
26. EUROPE TELEMEDICINE MARKET WORTH...
27. HEALTHCARE AND THE ENVIRONMENT...
28. ESA BUSINESS INCUBATION CENTRES...
29. PORTABLES HEALTHCARE TECHNOLOGIES GMBHON...



This growth in the volume of healthcare data collected is not only attracting interest from insurance companies wishing to tap into it for a closer understanding of their clients' behaviour, it is also propelling the rise of **healthcare digital platforms**. Precedence Research predicts 17.8% annual growth in healthcare cloud computing by 2027³⁰. To date, the largest platforms have emerged in China and the United States, but new players are now emerging in Europe providing personal, patient-doctor, pharmacy and even national platforms. These data platforms are paving the way for a wider adoption of AI in the global healthcare industry with increasing needs for automated evidence-based decision-making.

By 2025, 20% of medical services could be replaced by AI, especially in diagnosis, prevention and monitoring³¹. **Computer vision**, used extensively in space remote sensing, has become key in reducing the burden on healthcare professionals in image analytics. Technology transfer can therefore benefit both sectors.

Moreover, the use of **digital twins of patients, patient groups or even populations** to test therapies before they are applied is becoming increasingly widespread. These are being used by start-ups driving pharma innovation, most notably, accounting for 63% of all new prescription drug approvals over the last five years³². Furthermore, the healthcare industry is also leveraging **augmented reality (AR)** and **virtual reality (VR)** for much the same reasons as the space industry, opening the door to synergies, between the two sectors. Technology that can help train or otherwise prepare surgeons prior to surgery are currently in high demand in the sector. Surgical Theatre software³³ sets a compelling precedent for AR technology in aerospace training [Israeli Air Force] being redeveloped to train surgeons.



Surgical Theater's 360°-3D XR Visualization
[source: Surgical Theater]

COVID-19, for its part, further accelerated the digitalisation of the industry and became a major driver for a number of digital applications:

COVID-19 SHORT- AND MID-TERM EFFECTS

Widespread use of **telemedicine** as well as virtual and innovative health management tools

Leverage of **interoperability** and **analytics** in clinical decision support

Use of **robots** and **virtual assistants** to treat highly contagious patients

Augmented demand for **tele-radiology** infrastructure and services

The value added by the space sector to digital healthcare services is highlighted by several activities that ESA is currently undertaking. In collaboration with the UK National Health Service (NHS) and the UK Space Agency, ESA is for example promoting innovative solutions exploiting space technologies for the benefit of the NHS ecosystem³⁴.

ESA is also supporting the role of satellite in **5G/6G** development, key enabler for future digital applications.

EXAMPLES OF AREAS WHERE SPACE ADDS VALUE

Real-time monitoring (e.g. IoT, wearables, sensors) to monitor the patient's condition for preventative care

Applications bringing people together during isolation periods to reduce social exclusion and improve mental health

Timely diagnoses, second opinions, treatment adjustments, etc. made possible by the faster sharing of patient data among doctors, ambulances and hospitals

Remote diagnosis by enabling patients to engage with doctors through real-time telepresence systems (e.g. videoconferencing, immersive reality)

Doctors in remote locations to receive support or training using telepresence systems (e.g. immersive reality) or the use of robotics

Monitoring of patient recovery and condition management in rural areas (e.g. through their activity levels)

30. HEALTHCARE AND THE ENVIRONMENT...
31. FUTURE OF HEALTH (ROLANDBERGER.COM)...
32. BIG PHARMA'S SCRAMBLE TO INVEST IN START-UPS...
33. VIRTUAL REALITY FOR SURGERY | PRECISON XR...
34. [HTTPS://BUSINESS.ESA.INT/FUNDING/NHS-FUTURE...](https://business.esa.int/funding/nhs-future...)



Public Health Management



Digital technologies can support health infrastructure and logistics by integrating care, helping identify and reduce risks, helping manage the health needs of the population and improving the quality of data flow to deliver timely, efficient and safe care. Emerging features include continuous clinical monitoring, 3D printing for surgery, and the use of smaller and portable devices. **Centralised digital hubs** to enable decision-making are also becoming critical. Health Data Research UK and the German Medical Informatics Initiative are just some of the national schemes in Europe aiming to pool big health data (BHD) for exploitation by researchers, institutions, citizens, start-ups, etc. The European Commission, under its EU4Health programme³⁵, has also committed to creating a common Health Data Space³⁶ (eHDSI) over the period 2019–2025.

Technologies will also play a key role in providing enhanced planning, synchronisation and collaboration in the supply chain.



HEALTH INFRASTRUCTURE

Provide connectivity, security and robustness to IT infrastructure for:

- Data sharing/storing of electronic health records
- Hospital operations
- Disease / pandemic tracking (tracing and warning apps)

Environmental/EO data to support national data hubs in:

- Pandemic and disease surveillance
- Population and health management
- Environmental risks including air pollution



SUPPLY CHAIN

Provide real time tracking capabilities for:

- A clearer picture of where medication doses sit in the hospital's supply chain during the planning phase
- Improved visibility on consignment inventory and redirecting inventories in real time to areas experiencing shortages

Connectivity in remote areas to enable:

- IoT and M2M solutions for supply chain monitoring
- Drones to carry out BLOS deliveries of vaccines, medication etc.

35. EU4HEALTH (EUROPA.EU)...
36. EUROPEAN HEALTH DATA SPACE (EUROPA.EU)...
37. LIFE LINE: APOLLO'S DIGITAL DISRUPTION TO DELIVERY...



Moreover, space data and technologies can help tackle issues associated with One Health and the environment.

WHAT IS ONE HEALTH?

One Health analyses the impact of climate change on human as well as animal health, vector-borne diseases, particularly zoonotic diseases (shared between animals and humans), and water-borne diseases¹. Experts see a link between pandemics and the biodiversity and climate crisis caused by humans: increasing environmental devastation, habitat degradation and the accelerating effects of global warming are leading to increased wildlife-human interaction. More than 75% of emerging infectious diseases in humans are zoonotic. In the IPBES #PandemicsReport Escaping the 'Era of Pandemics'³⁸, it is estimated that the cost of reducing the risk of pandemics with a view to preventing them is 100 times less than the cost of responding to such pandemics.

In this context, remote sensing can help forecast and model the spatio-temporal evolution of diseases. Only through satellites can vast territories or whole regions be scanned, analysed and correlated with ground data. Space therefore supports early warning systems through risk modelling and mapping, as well as through the identification and visualisation of hotspots to manage epidemics. ECDC has set up a web portal called the **E3 Geoportal**³⁹ to collect and make available a wide range of information on infectious disease epidemiology in Europe, using among others EO data. For its part, ESA is supporting initiatives such as the AIDEO project⁴⁰ that explores the use of AI applied to a pool of EO datasets in the context of the West Nile Disease, a widespread zoonosis caused by a vector-borne virus. ESA is also working hands in hands with the World Health Organization (WHO), supporting crisis management that can lead to epidemics. During the COVID-19 crisis, NASA, JAXA and ESA set up, in an unprecedented collaboration, the **COVID-19 Earth Observation Dashboard**⁴¹ to gauge the effects of the pandemic on social, economic and environmental variables. At the same time, ESA and the European Commission have developed the twin **Rapid Action Coronavirus and Earth observation (RACE)**⁴² platform for user-friendly, free access to data.



COVID-19 Earth observation dashboard

Satellites can also be used to detect the emergence of **water-borne diseases** as parameters such as turbidity, suspended matter, chlorophyll-a, harmful algae bloom and trophic state classification can be derived from EO imagery. For example, the ECDC uses EO data to monitor Vibrio bacteria in the Baltic Sea⁴³. Moreover, satellites are key to monitoring **heat exposure** that can place significant strain on the cardiovascular system⁴⁴ and **air pollution**, which results in multiple adverse health outcomes such as lung dysfunction, cardiovascular diseases or coronary artery diseases. Sentinel-5P for example monitors methane, formaldehyde, aerosol, carbon monoxide, nitrogen dioxide and sulphur dioxide in the atmosphere.

➔ Throughout all 3 domains, **Medical and Biomedical Research, Telemedicine and digital health** and **Public Health Management**, the analysis has shown that building blocks and critical benefits can be leverage through space technologies and services, providing valuable infrastructure and assets for future Healthcare and Medicine.

38. IPBES #PANDEMICREPORT: ESCAPING THE 'ERA OF PANDEMIC'...
39. ECDC GEOPORTAL | E3 NETWORK (EUROPA.EU)...
40. VECTOR-BORNE DISEASE CIRCULATION PREDICTED WITH EO...
41. ESA - SPACE AGENCIES JOIN FORCES TO PRODUCE GLOBAL...
42. RAPID ACTION FOR CITIZENS WITH EARTH OBSERVATION...
43. WATER-BORNE DISEASES: EO SYSTEM FOR THE COASTAL...
44. HEAT EXPOSURE AND CARDIOVASCULAR HEALTH: A SUMMARY...

A large container ship is shown from an aerial perspective, sailing on a deep blue ocean. The ship's deck is densely packed with multi-colored shipping containers in shades of red, blue, yellow, green, and white. The ship's white superstructure, including the bridge and funnels, is visible at the stern. The ship is moving towards the right, leaving a white wake behind it. The sky is a pale, hazy blue, suggesting a clear day.

**E0 commercialisation
for maritime**

E0 commercialisation for maritime

Introduction to the maritime sector

The maritime sector plays a pivotal role in the global economy, **serving as a lifeline for international trade**, transportation, energy production, and as a vital source of food. Shipping remains the most cost-effective and efficient mode of transporting goods across long distances. Roughly 95% of global trade by volume is carried out through maritime routes, making ports and shipping lanes essential components of the global supply chain. The fisheries and aquaculture sector also plays a vital role in **providing food for millions of people worldwide**, especially in coastal regions and developing countries, where seafood often constitutes a primary source of animal protein. Moreover, the maritime industry provides numerous employment opportunities.

However, the industry is under increasing pressure to **reduce its environmental impact**. Issues such as air and water pollution,

greenhouse gas emissions, and oil spills pose significant challenges. Stricter regulations and demands for cleaner, more sustainable systems or methodologies are driving the industry to adopt greener technologies and practices. Growing global food demand which to some extent can clash with the sustainability and preservation of our seas is also resulting in increasing pressure for efficiency and digitalisation within the industry. Moreover, **geopolitical issues surrounding illegal maritime migration, border security, smuggling and piracy** are fast becoming a high priority for many governments. As a result of these challenges, Earth Observation-based services are becoming more and more accepted and adopted within the industry thanks, to their ability to address the sustainability and efficiency requirements of the sector.



THE SECTOR IN NUMBERS

95%
of global trade by volume is transported and delivered by the shipping industry

11 billion tons
Cargo transported annually

50,000
Merchant vessels in operations globally

Source for numbers

Zoom in on Europe

Europe is home to some of the world's busiest and most significant seaports, including Rotterdam, Antwerp, Hamburg, and Marseille. These ports serve as crucial gateways for international trade. Moreover, Europe is the home of many major shipping companies that operate globally. Greek, Danish, and Norwegian shipping companies, in particular, play a significant role in the international shipping market. Stakeholders across the European maritime landscape include several **maritime authorities** who are looking for new and more efficient ways to fulfil their mandates. Within the maritime Research and Innovation (R&I) ecosystem exciting innovations are being developed for application in challenging environments and service providers delivering value to the market with cutting-edge technologies for end users such as port authorities, national governments, shipping companies, fisheries, and construction companies.

Various authorities and public agencies such as the **International Maritime Organization (IMO)**, the **European Maritime Safety Agency (EMSA)**, the **Directorate-General for Maritime Affairs**

and **Fisheries (DG MARE)**, the **European Fisheries Control Agency (EFCA)** and several national agencies including the UK's **Maritime and Coastguard Agency** are all concerned with guiding how the maritime sector is managed. These entities drive many initiatives and regulations such as the **International Convention for the Safety of Life at Sea (SOLAS)**, the **European Union Maritime Security Strategy (EUMSS)**, and the **Common Fisheries Policy (CFP)**. Numerous industry associations also play a vital role in **making sure the voice of the industry is heard at political/international levels**. They routinely promote and advance the common interests of businesses and promote the proliferation of common industry standards.

Europe has many entities involved in highly sophisticated R&I in the maritime sector. Numerous institutions and universities across the continent are looking into issues facing the maritime sector, such as the **optimisation of port operations, wave energy, dark vessel monitoring, autonomous shipping, and harmful algal blooms (HABs)**.

Critical challenges facing the maritime sector

Illegal maritime migration in Europe is at its highest level since 2016. In 2022, the number of irregular border crossings into Europe via the Central Mediterranean route rose to over 100,000 and the number of people crossing the English Channel rose to over 70,000, accounting for a 51% and 37% increase on the previous year respectively¹.

Maritime safety incidents are also on the rise. A large part of these increases can be attributed to a post-pandemic increase in seaborne trade. Machine damage or failure has been the main driver of this surge in safety incidents, increasing by 24% in 2021 and 13% in 2022. It is also possible that an improved approach to incident reporting drove these numbers up². Digitalisation (AI, machine learning and cloud connectivity) is enabling real-time processing of data, leading to actionable insights and more reliable decision-making for the maritime security/safety stakeholders. **However, adequate training, awareness, and accountability among the workforce are still crucial** in minimising human errors and ensuring safe usage of digital systems³.

Demand for sustainable seafood is also a strong and growing trend from consumers. The number of Marine Stewardship Council (MSC) certified fisheries and supply chain organisations are increasing year on year, with 550 fisheries in 2023, up from 539 the previous year. The MSC is the international not-for profit organisation responsible for the world's most widely used sustainable seafood ecolabel⁴.

At European level, maritime transport represents **3 to 4% of the EU's total CO₂ emissions, or over 124 million tonnes of CO₂ in 2021**. There is increasing pressure on the sector to reduce its emissions, hence the forthcoming introduction of the maritime sector to the **EU Emissions Trading System⁴**.



1. EU'S EXTERNAL BORDERS IN 2022...
2. WHAT ARE THE LATEST MARITIME SAFETY TRENDS...
3. CELEBRATING SUSTAINABLE SEAFOOD...
4. EU EMISSIONS TRADING SYSTEM (EU ETS) POLICY_EU_ETIS...



How space adds value for the maritime sector

Space technologies play a crucial role in enhancing various aspects of the maritime sector. The integration of satellite-based technologies and space-derived data has significantly improved the efficiency, safety, and sustainability of maritime activities. Earth Observation (EO) data can help monitor **weather patterns, sea conditions, and environmental changes**. This data is invaluable in helping maritime operators make informed decisions about routes, avoiding storms, and ensuring the safety of vessels. Satellites also help monitor and manage fisheries by **tracking vessel movements, identifying illegal fishing activities, monitoring maritime pollution such as oil spills or CO2 emissions, and assessing the health of marine ecosystems**.

Given the huge focus on maritime security, EO is proving invaluable by providing continuous surveillance of maritime areas. Satellite imagery assists in **monitoring shipping routes, detecting suspicious activities, and preventing illegal activities such as piracy, illegal fishing and smuggling**. Space technologies also enable connectivity for autonomous and remotely-operated ships. Satellite communications ensures continuous data exchange, navigation updates, and remote control capabilities for smart shipping applications. For this application in particular, EO better enables the acquisition of

essential information such as sea and weather conditions, and when in colder regions, enables safe navigation around sea ice. Offshore renewable energy project developers and investors can use EO to **identify the most suitable areas for the exploitation of renewable energy sources**, plan their development and monitor their integrity/status.

EO-enabled marine surveying and mapping of the seabed and coastal areas is important in **determining prospective infrastructure sites**. It also helps construction companies in continuously monitoring the progress achieved on construction sites and in reporting on this progress to their clients (e.g., infrastructure owners / operators). Maritime insurers, investors and asset managers all rely on **evaluating the levels of risk exposure**, using probabilistic approaches of the events, exploiting historical data, and performing climate reanalyses over several years. Again, EO can aid in all of this.

In support to EO, it should be noted that **Global Navigation Satellite Systems (GNSS) and Satellite Communications** are extremely useful for the maritime sector by as they provide accurate and reliable positioning information as well as connectivity for safety, business critical and operational services.

Some space related initiatives in Europe

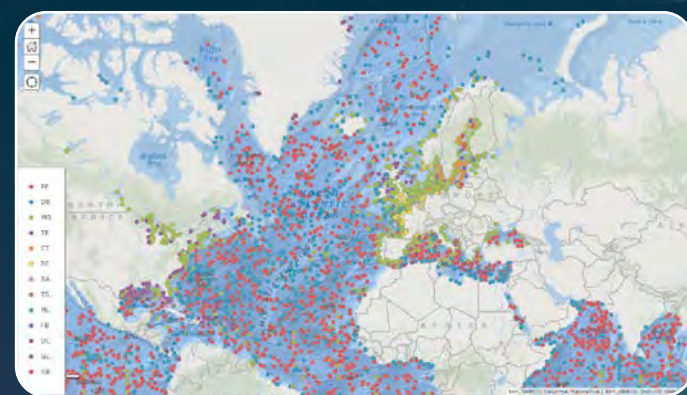
A major anticipated trend in the industry is the proliferation of **Maritime Autonomous Surface Ships (MASS)**. There is currently a lot of regulatory work being developed at IMO level on this topic. The non-mandatory MASS code is expected by 2024 and, based on the application of the non-mandatory MASS Code at an initial stage, the mandatory MASS Code is expected to come into force on 1 January 2028. **EMSA is currently in the process of developing a risk-based assessment tool (RBAT)⁶ for the evaluation of new Maritime Autonomous Surface Ships (MASS) projects**. It is expected to be finalised in 2023 and results will be shared with relevant stakeholders. The regulatory and technical impact of MASS technology in the shipping industry is expected to be transformative with EO and GNSS both considered important data sources for this initiative.

An important development in the sector is the incorporation of the shipping industry's emissions into the EU **Emissions Trading System⁷** in 2024. This will open opportunities for EO companies **to aid in the monitoring, reporting and verification of emissions** coming from the shipping industry.

The **Copernicus Marine Service (CMEMS)⁸**, is one of the six services provided by the EU's Earth Observation and Monitoring programme and is dedicated to providing accurate information on the global and regional marine environment. Other EU initiatives include the **European Marine Observation and Data Network (EMODnet)⁹** and the **European Spatial Planning Platform (MSP)¹⁰** which are respectively enhancing access to marine

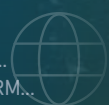
data, data products, services and projects to better understand European and oceans as well as advancing the use of EO in maritime spatial planning.

The **European Space Agency (ESA)** is involved in several projects aimed at supporting the maritime sector using EO and other advanced technologies.



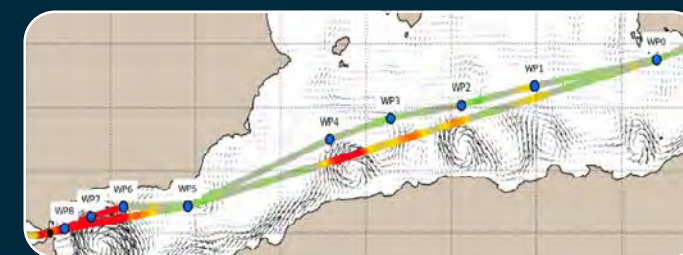
In situ observing platforms in global CMEMS

5. AUTONOMOUS SHIPPING...
6. MARITIME AUTONOMOUS SURFACE SHIPS (MASS)...
7. REDUCING EMISSIONS FROM THE SHIPPING SECTOR...
8. COPERNICUS MARINE SERVICE...
9. EUROPEAN MARINE OBSERVATION AND DATA NETWORK...
10. THE EUROPEAN MARITIME SPATIAL PLANNING PLATFORM...



ALongRoute¹¹, supported by ESA BIC Greece, focuses on leveraging AI-powered ocean forecasts to guide vessels efficiently, ensuring smoother, greener, safer, and more cost-efficient maritime transport. The project's high-precision data is instrumental in enabling marine management software companies to optimise shipping performance significantly. The groundbreaking AI models employed can generate marine weather forecasts with exceptional accuracy and resolution.

Amphitrite¹², another ESA-supported project, contributes by providing innovative, reliable, and accurate ocean data necessary for informed decision-making at sea. Recognising the uncertainties in operational ocean models, Amphitrite employs artificial intelligence to merge multiple satellite and in-situ data. This approach ensures the delivery of reliable information tailored to the specific needs of maritime actors, addressing the complexities associated with decision-making in maritime operations.



Short term optimal routing

Skytek¹³, a recipient of ESA ARTES programme funding, developed a demonstrator titled 'Next Generation – Recognised Maritime Picture' (NG-RMP). The project utilises emerging Satellite Automatic Identification System (AIS) vessel position technology to create a dynamic and improved Recognised Maritime Picture. This enhanced capability aids the Irish Naval Service in identifying 'vessels of interest' and provides real-time aggregated information on vessels for the insurance industry. The system was further enhanced by the integration of high-resolution EO datasets, SAR and machine learning. This provided insurance organisations at major ports worldwide with the capability to detect dark activities on vessels, calculate the value of cargo and make calculated risk assumptions regarding the vessels.

Under the support of ESA BIC Finland and ESA's **Business Applications and Space Solutions (BASS) program, Awake.AI¹⁴** has developed the Marketplace platform to enhance transparency and streamline operations in ports. This platform allows port service providers to effortlessly create and manage orders for various services, whether linked to a vessel port call or not. The Marketplace represents a significant step towards optimising port operations and fostering efficient communication within the maritime industry. A wide range of datasets are used including EO as well as vessel AIS and GNSS to make the marketplace smarter and provide added value.

Finally, more specifically in the field of communications, ESA also supports the **Sternula¹⁵** project, which aims to establish global maritime IoT satellite connectivity for safety and navigation. This initiative focuses on enhancing the communication infrastructure to enable seamless and secure data exchange in the maritime domain.

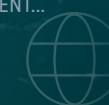
It is clear to see that there are numerous synergies between the space and maritime sectors and ESA, with its range of support programmes, is committed to continuing its collaboration with the maritime sector.

The BASS programme will launch its Space for Maritime Task Force beginning this year which aims to contribute to sustainability in the sector by exploiting digital and space technologies. Furthermore, a workshop was organised with EMSA to discuss WHF Data Exchange Systems (VDES) [December 2023]¹⁶ as well as a "Space for Blue" workshop exploring synergies and challenges for stakeholders around the North and Baltic Seas (February 2024)¹⁷. In addition, ESA's Earth Observation programme InCubed has recently launched its call focusing on developing innovative and commercially viable products and services using space borne Earth observation in the maritime domain¹⁸. Finally, the second edition of the ESA Commercialisation Days on Transportation had a dedicated session in discussing space and maritime synergies (November 2023)¹⁹.

ESA continues to be an active partner for a wide range of organisations and activities across the maritime sector, helping them to harness space technologies to improve life on Earth. Funding and technical support is available to organisations directly or indirectly involved in the sector, from support for start-ups via the ESA BIC network²⁰ to the development of science, technical and commercial projects through the BASS²¹ and InCubed²² programmes.



11. ESA COMMERCIALISATION DAYS: TRANSPORTATION EVENT...
12. ESA COMMERCIALISATION DAYS: TRANSPORTATION EVENT...
13. EMERGING SATELLITE AIS TECHNOLOGY TO GENERATE...
14. AWAKE.AI MARKETPLACE: REVOLUTIONISING THE MARITIME...
15. ESA COMMERCIALISATION DAYS: TRANSPORTATION EVENT...
16. JOINT EMSA-ESA WORKSHOP ON VDES...
17. "SPACE FOR BLUE" EVENT TO BE HELD IN FEBRUARY...
18. INCUBED – MARITIME THEMATIC CALL...
19. ESA COMMERCIALISATION DAYS: TRANSPORTATION EVENT...
20. ESA BUSINESS INCUBATION CENTRES...
21. YOUR BUSINESS POWERED BY SPACE...
22. INCUBED IS AN ESA PROGRAMME MANAGED...





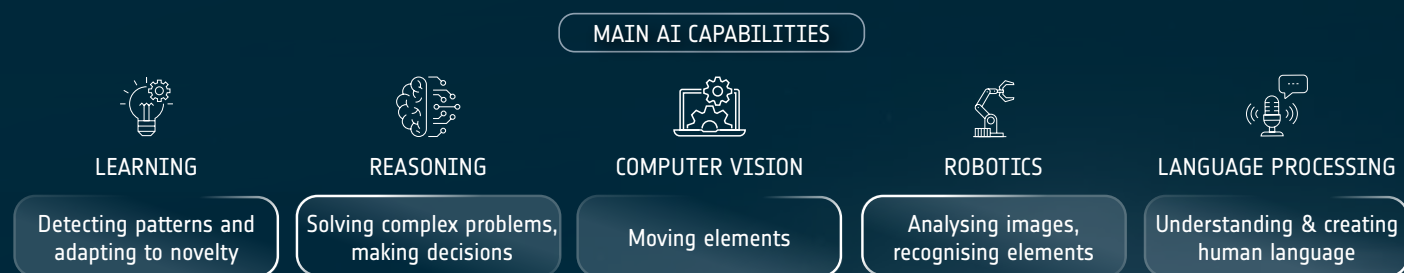
AI for space



Proliferation of commercial use cases for AI

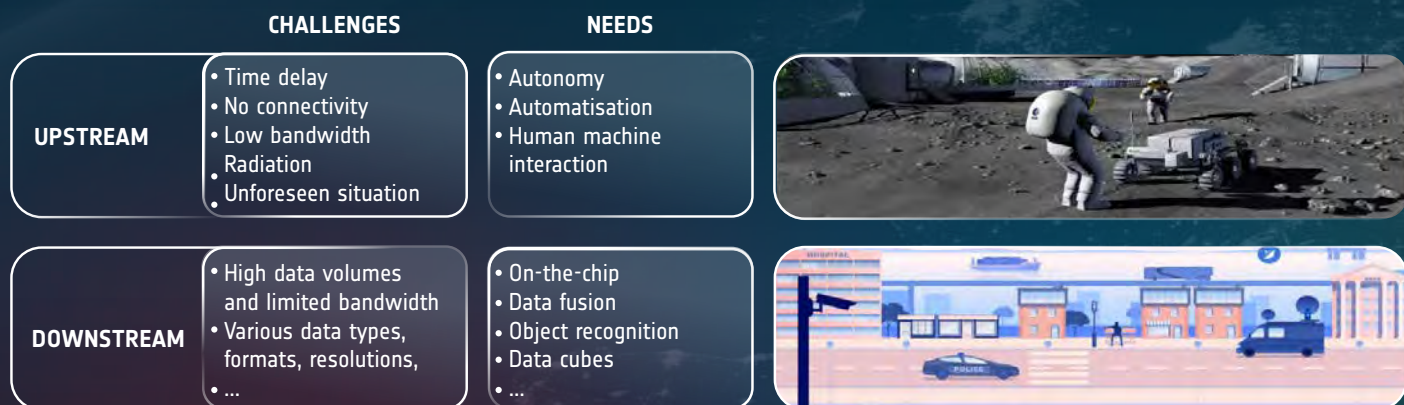
Artificial intelligence (AI) has, thanks to its impressive capabilities that include offering enhanced decision-making and productivity gains, become one of the fastest growing of all technology sectors. According to GlobalData's 2023 TMT Predictions¹, the AI industry will be worth \$93bn in 2023, up 12% from 2022. Commercial uses of AI are proliferating in advanced and emerging markets alike, with highly successful examples of implementation in the healthcare (diagnosis and drug discovery), manufacturing (predictive maintenance) and energy (power transmission optimisation) industries.

The complexity that characterises the space sector environment is a very significant driver when it comes to the penetration of AI in the space industry. A number of applications of AI for space are either being thoroughly investigated or have been successfully implemented in order to respond to both upstream and downstream needs.



The **AI Special Interest Group Dedicated to Space and Related Sciences** created by ESA and the Confederation of Laboratories for Artificial Intelligence Research in Europe² (CLAIRE) in September 2019 is carrying out investigations in this area. So too is **ESA's Advanced Concepts Team (ACT)**³, which is very active in deep learning research, and the first **ESA Φ-lab** in Italy⁴, which has been promoting the development of AI on board Earth observation missions.

In addition, the **Software Systems Division of ESA's Directorate of Technology, Engineering and Quality** has been investigating onboard AI solutions and natural language processing applications in the space sector.



1. TECH, MEDIA AND TELECOM (TMT) PREDICTIONS 2023...
2. HOME | CLAIRE – CONFEDERATION OF LABORATORIES...
3. ESA – ADVANCED CONCEPTS TEAM...
4. ABOUT | Φ-LAB (ESA.INT)...



AI solutions for the upstream space sector: use cases and opportunities

AUTONOMOUS NAVIGATION FOR SPACECRAFT AND ROVERS

In the upstream segment, developing **autonomous spacecraft** capable of operating solely using AI will be key to exploring new parts of the Solar System and reducing mission costs. AI will notably be crucial aboard **space rovers** given that reaching Mars with a signal, for example, takes between three and 22 minutes, depending on the position of Mars in relation to Earth. Machine learning can also be used to prepare rovers, using images of new harsh environments. ESA's Hera planetary defence mission, meanwhile, will make use of AI as it steers itself through space towards an asteroid⁵, autonomously fusing data from various sensors to build up a model of its surroundings and make decisions on board.



ESA's Hera planetary defence mission

SPACE ENGINEERING

Natural language processing can help accelerate the design of space missions either by better handling the data accumulated during previous missions or by serving as a **model-based systems engineering (MBSE) virtual assistant**⁶, thus providing traceability of discussions and decisions throughout the entire life cycle of a project. Valispace, for example, has leveraged AI to develop a state-of-the-art software tool that enables engineers to collaborate in real time, iterate design options and keep track of technical changes while analysing and visualising their data.



Valispace's assisted engineering software

PLANNING, IN-SPACE OPERATIONS AND LOGISTICS

Space systems require intricate planning based on numerous mission requirements and conflicting constraints. AI can address critical scientific and engineering mission restrictions and optimise the timeline to meet all such requirements. Italian start-up AIKO⁷, a participant in ESA's Technology Transfer programme⁸, has developed orbital_OLIVER⁹, a software which enables autonomous operations to be performed during space missions. It provides spacecrafts with the ability to process data, make decisions in real time and even replan missions if necessary. Nevertheless, the ability for humans to be able to understand the schedule decisions made by AI is crucial. In this context, the Software Systems Division of ESA's Directorate of Technology, Engineering and Quality is also working on the use of **explainable AI**¹⁰ (XAI).

In January 2021, ESA and the German Research Centre for Artificial Intelligence (DFKI) established ESA_Lab@DFKI, a technology transfer lab that works on AI systems for satellite autonomy, collision avoidance capabilities, and more. Based in Portugal, ESA BIC alumnus Neuraspace has already received €2m in funding to accelerate the growth of its AI space debris monitoring and satellite collision avoidance platform. The **space situational awareness (SSA)** market alone is projected to be worth \$2bn by 2030¹¹.



orbital_OLIVIER software

5. ESA – ARTIFICIAL INTELLIGENCE IN SPACE...
6. MBSE AT ESA: STATE OF MBSE IN ESA MISSIONS AND ACTIVITIES...
7. AIKO SPACE | AIKO...
8. ESA – TECHNOLOGY TRANSFER PROGRAMME...
9. AIKO SPACE...
10. AI-AND-INTERPRETABILITY-POLICY-BRIEFING...
11. SPACE SITUATIONAL AWARENESS MARKET SIZE...



With volumes of debris continuously on the rise, and given the difficulty of modelling the uncontrolled dynamics and kinematics of such debris in free-floating conditions, AI is key to tackling the issue of orbital capture. ESA's first **debris removal** project with Swiss start-up ClearSpace, planned for 2025, will see the ClearSpace-1 chaser aircraft locate debris autonomously with the help of AI-enabled cameras embedded in its system.

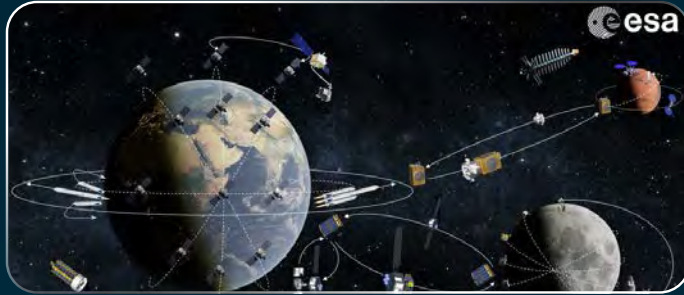
DATA PROCESSING AND TRANSMISSION

In the past, ground infrastructures and existing cloud networks were used to distribute, store and convey all of the data collected from satellites, spacecrafts or rovers in an unfiltered manner. With increasing amounts of data, limited bandwidth and the need for data to be real-time, this model no longer satisfies industry needs, nor does it meet expectations in terms of cost. Edge computing is responding to this issue, making it possible for local data analysis and processing to be performed, creating devices that leverage machine learning models to produce actionable information. Dublin space-tech company Ubotica Technologies¹², for example, recently unveiled its latest hardware platform designed to get AI into orbit to increase computing performance¹³.

AI can be used on board spacecraft to reduce dependence on Earth and accelerate results needed to allow decisions to be taken or for experiments, such as in zero gravity, as well as to **pre-filter data sets** to be sent to ground segments for processing. FSSCat, launched in September 2020, was the first European Earth observation mission to carry AI on board in the form of Φ -sat-1¹⁴. It has demonstrated the potential of AI as a tool for cloud detection on board a hyperspectral imaging mission: only meaningful, useful data are transmitted to the end user, both minimising the required data bandwidth and reducing latency. Bolstered by such successes, the Φ -lab ESRIN model is now being replicated across Europe. In March 2022, ESA signed a letter of intent with AI Sweden to set up a pilot development of Φ -lab Sweden¹⁵, a collaboration that will develop solutions in the areas of edge computing and learning in space.

ASTRONAUT SUPPORT AND HEALTH

AI-enabled assistants can support astronauts in space. In 2018, the German Space Agency (the DLR), in partnership with Airbus and IBM, launched an **AI assistant** to support its astronauts in their daily tasks on board the International Space Station (ISS). CIMON, the Crew Interactive Mobile Companion, can perform tasks on board the ISS and is able to see, speak to, hear and understand the astronauts. Even more crucial is the potential of AI-enabled solutions to monitor crew health in the harsh environment of space. The potential for technology transfer to tele-health applications on Earth has been amply demonstrated in recent years.



In-space logistics



AI as an onboard tool for cloud detection



CIMON AI assistant

- 12. [HOMEPAGE | UBOTICA TECHNOLOGIES...](#)
- 13. [DUBLIN'S UBOTICA REVEALS LATEST PLATFORM TO SEND AI...](#)
- 14. [PHISAT-1 NANOSATELLITE MISSION...](#)
- 15. [ESA AND AI SWEDEN SIGN LETTER OF INTENT...](#)

AI solutions for the downstream space sector: use cases and opportunities

EARTH OBSERVATION DATA ANALYSES

While AI can also be used to analyse telemetry and product data from spacecrafts and robotic systems, it is principally for the analysis of satellite data for downstream use cases that it has come under the spotlight. Computer vision models, to cite one example, enable automated feature detection, thus effectively transforming satellite image data into intelligible insights. AI also plays a key role in integrating data from both terrestrial and space-based technologies¹⁶, for example to analyse geo-referenced satellite data on cars detected in car parks and merge it with past transactions, website searches and weather forecasts, to predict future sales



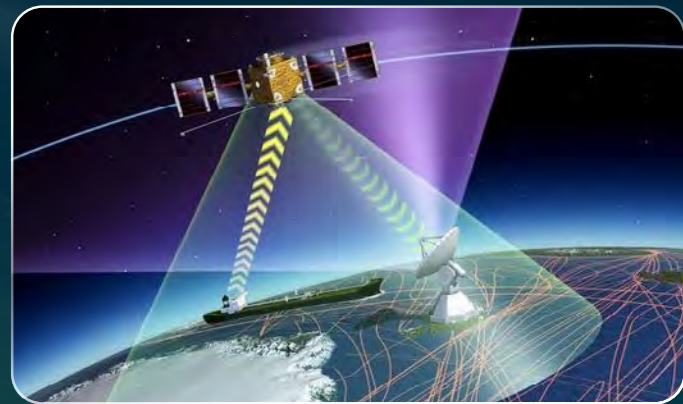
Destination Earth initiative

Earth observation data and value-added services, a market with revenues predicted to reach almost €5.5bn by 2031¹⁷, has thus become a key downstream area in which AI use is increasing significantly, while still showing further room for growth. ESA is working towards a Digital Twin of Earth¹⁸ that combines Earth observation data and AI to help visualise and forecast natural and human activity on the planet. This ability to anticipate and understand the impact of climate change and thus improve climate resilience through AI is attracting the attention of the insurance and finance sectors, in particular.

ESA, through its **InCubed programme**¹⁹ and its **Business Incubation Centres**²⁰, has already supported numerous European businesses that apply AI to Earth observation data to tackle an ever-increasing number of use cases such as environmental monitoring²¹, cultural heritage²² and wildfire assessment²³. Specifically, AI4EO²⁴ is dedicated to organising cutting-edge AI-based challenges in partnership with esteemed partners and sponsors.

AUTONOMOUS NAVIGATION FOR TERRESTRIAL TRANSPORT

AI can also be applied to autonomous navigation in the downstream segment, for example in shipping and driving. In the shipping sector, safe and efficient autonomous navigation on the seas is a major challenge. The ESA Machine Learning Sensor Fusion for Autonomous Vessel Navigation project is already applying AI to achieve autonomous situational awareness, enabling a ship to reliably sense its own environment.



Autonomous vessel navigation

- 16. [ARTIFICIAL INTELLIGENCE KICK-START...](#)
- 17. [HTTPS://WWW.EUSPA.EUROPA.EU/SITES...](https://www.euspa.europa.eu/sites...)
- 18. [ESA - WORKING TOWARDS A DIGITAL TWIN OF EARTH...](#)
- 19. [INCUBED \(ESA.INT\)...](#)
- 20. [ESA BUSINESS INCUBATION CENTRES...](#)
- 21. [MARKET TREND: COMMERCIAL SPACE OPPORTUNITIES...](#)
- 22. [COMMERCIAL MARKET TREND: SPACE FOR CULTURAL HERITAGE...](#)
- 23. [MARKET TREND: WILDFIRES AND COMMERCIAL SPACE-BASED...](#)
- 24. [AI4EO - ESA'S AI INITIATIVE...](#)



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