



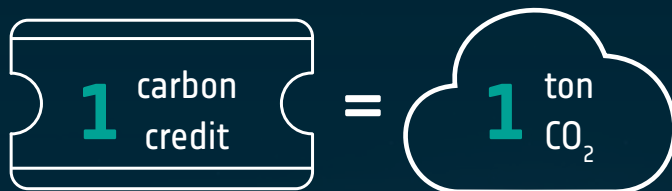
Space and carbon markets: harnessing the power of space technologies and carbon markets for a sustainable planet

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.

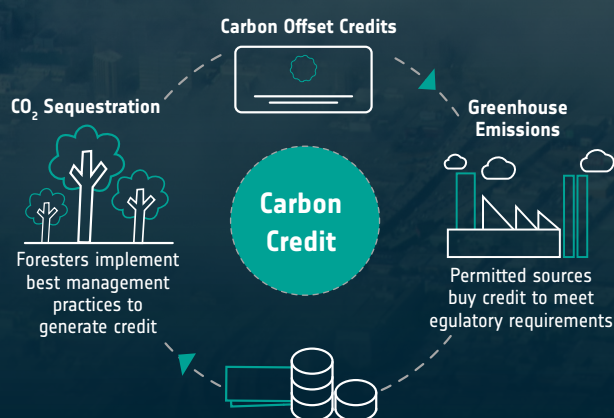


Emissions trading systems (ETS) worldwide in 2023³

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.



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.

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

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

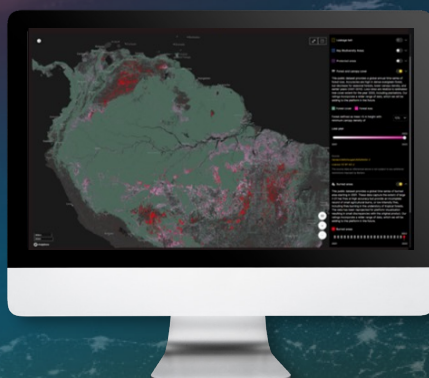
Blue carbon credits correspond to the carbon stored in **coastal and marine ecosystems**, with the main coastal ecosystems being mangroves, sea grasses and salt marshes¹⁵. Although the monitoring of mangroves is more advanced, as illustrated by the Global Mangrove Watch¹⁶ map, the application of blue 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

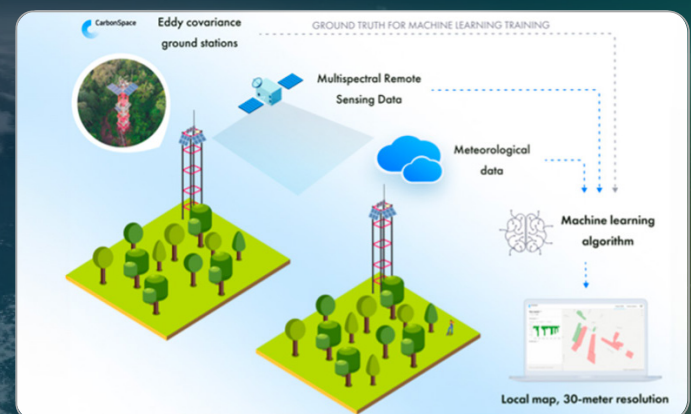
RESEARCH AND APPLICATIONS FOR TERRESTRIAL CARBON ECOSYSTEMS

BeZero exemplifies the rising trend of greater integration of satellite monitoring in the VCM¹⁸. This carbon-rating company has recently partnered with **Kayros**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.



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



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 KAYROS...
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...



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.

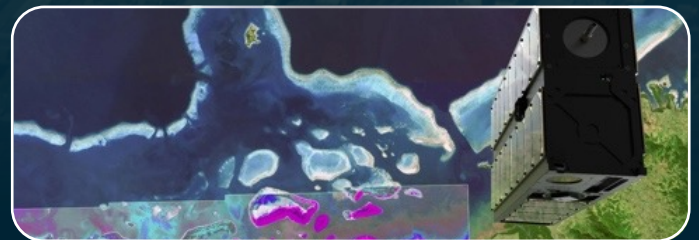
Concerning agriculture, **Green Emissions**, incubated by ESA BIC Sweden, aims to become a voluntary carbon marketplace, using blockchain to enable the satellite monitoring of biomass growth to trigger the payment of carbon credits once the carbon has actually been absorbed²⁶. Green Emissions targets 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...

