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WORLD
ECONOMIC
FORUM

Amplifying the Global Value of Earth Observation

INSIGHT REPORT

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Contents

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Foreword

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Our collective ability to observe nature and the built environment is greater now than ever, in large part due to exponential growth in the capabilities of Earth-observing satellites. In recent years, several commercial and non-profit organizations have joined the ranks of national governments to observe Earth from orbit as a result of more flexible regulations and lower-cost access to space.

Through detailed, daily measurements, modern satellites and sensors can do much more than produce impressive images of Earth. They allow us to monitor Earth's vital signs, elucidate relationships between people and the planet and provide valuable insights for leaders across sectors. Renewables production, disaster response and sustainable sourcing are just a few of the areas that Earth insights can enhance. In concert with complementary in-situ data sources, analytics tools and a growing marketplace of user-focused services, Earth data is quickly approaching mainstream accessibility.

This study estimates that by 2030, the economic value of Earth insights could exceed $700 billion (nominal US dollars) and help reduce greenhouse gas emissions by 2 gigatonnes annually. This is an inspiring time to explore the transformative opportunity that Earth observation (EO) presents. As a vital component of the fourth industrial revolution, EO converges with artificial intelligence (AI), digital twins and climate technology to offer a powerful toolset for economic prosperity and sustainable growth. Advances in EO technology help illuminate our pathways to net zero and can inform action on nature and biodiversity protection.

This report by the World Economic Forum, in collaboration with Deloitte, showcases the dual economic and environmental value proposition of Earth observation data. It integrates perspectives from the EO community, a group of 40 industry, technology and climate leaders committed to driving sustainable value through EO applications. Together, we highlight opportunities for both proven and promising EO applications, quantify their value and offer strategies to amplify their global impact. We hope this publication provides insights for those in the EO ecosystem – and the potential beneficiaries of Earth data across industries – to build towards a more prosperous, sustainable and resilient future for the planet.

Executive summary

Earth observation has the potential to drive $3.8 trillion in economic benefit from 2023-2030 while positively impacting climate and nature.

Today, Earth observation (EO) is not only a focal point of the space industry and scientific community but also an engine for economic development. Data collected from space and other sensors can benefit a wide range of business interests, both by strengthening financial performance and by supporting compliance with environmental regulations. EO can play a helpful role in supporting organizations to advance climate and nature goals through verifying carbon reduction, understanding organizations' impacts and dependencies on nature, and identifying strategies that contribute to a nature-positive and net-zero economy.

With promising market trends and hundreds of possible applications, the global potential of EO is immense, but the extent of this potential has not yet been realized. As found in this study, the potential value-added from Earth data is estimated at **$266 billion** (nominal US dollars are used throughout this report) **in 2023**, a figure that is poised to grow to more than $700 billion in 2030 with a **cumulative $3.8 trillion contribution** to global gross domestic product (GDP) between 2023-2030. Most of that value comes from downstream applications in industry; approximately 94% of the total value possible by 2030 derives from applications in agriculture, electricity and utilities, government, public and emergency services, insurance and financial services, mining, oil and gas, and supply chain and transport.

At the same time, EO can inform interventions that stand to reduce greenhouse gas (GHG) emissions by more than 2 gigatonnes annually – measured in carbon dioxide equivalent (CO_2e). This figure is likely an underestimate, as it considers five leading EO applications with a demonstrated direct impact on GHG emissions, while numerous others exist with indirect effects. Yet, it still equates to approximately **3.6% of annual global emissions** today[1]

Importantly, applications for business goals and environmental goals are not mutually exclusive. In fact, they often go hand-in-hand. Activating the economic co-benefits of dual value applications for environmental monitoring, vulnerability analysis and supply chain monitoring is a promising mechanism to amplify the climate and nature impact of EO.

While EO is an extraordinary tool for creating both economic value and positive environmental impact, maximizing its value depends on a dramatic increase in end-user adoption. Achieving that calls for resolute strategies and investments to increase awareness of what is possible with EO, encourage innovation, advance core and enabling technologies, ensure equity in access to EO insights and bridge the gap between EO data and end-user solutions worldwide.

Introduction

Understanding Earth's systems – and human dependencies and impacts on them – is integral to sustainable economic development worldwide.

Earth observation (EO) has contributed to the global economy for decades. Initially underpinned by strong public sector contributions (particularly driven by defence and security interests), there is now an established and growing commercial EO industry. In just two years, from 2021 to 2023, the EO industry grew by more than 21%.[2] Driven by technology and business model innovation, the stage is set for continued growth – not only in the EO industry but also in EO's multitude of downstream applications.

Novel modelling undertaken in this study has illuminated the scale of opportunity that EO presents. By 2030, the potential economic value of EO could exceed $700 billion (nominal US dollars) globally, with applications across nearly all industries. It can also support initiatives that generate environmental benefits. Specifically, EO is a critical tool to inform policies, decisions and interventions that could eliminate up to 2 gigatonnes (Gt) of greenhouse gas (GHG) emissions every year while supporting a host of nature-positive strategies.

Increasing uptake across all regions and industries is key to unlocking EO's economic and environmental benefits. The scale of EO's dual value is compelling, but integrating EO into the global economy will depend on the innovation, investment and the collective actions of organizations throughout the EO value chain.

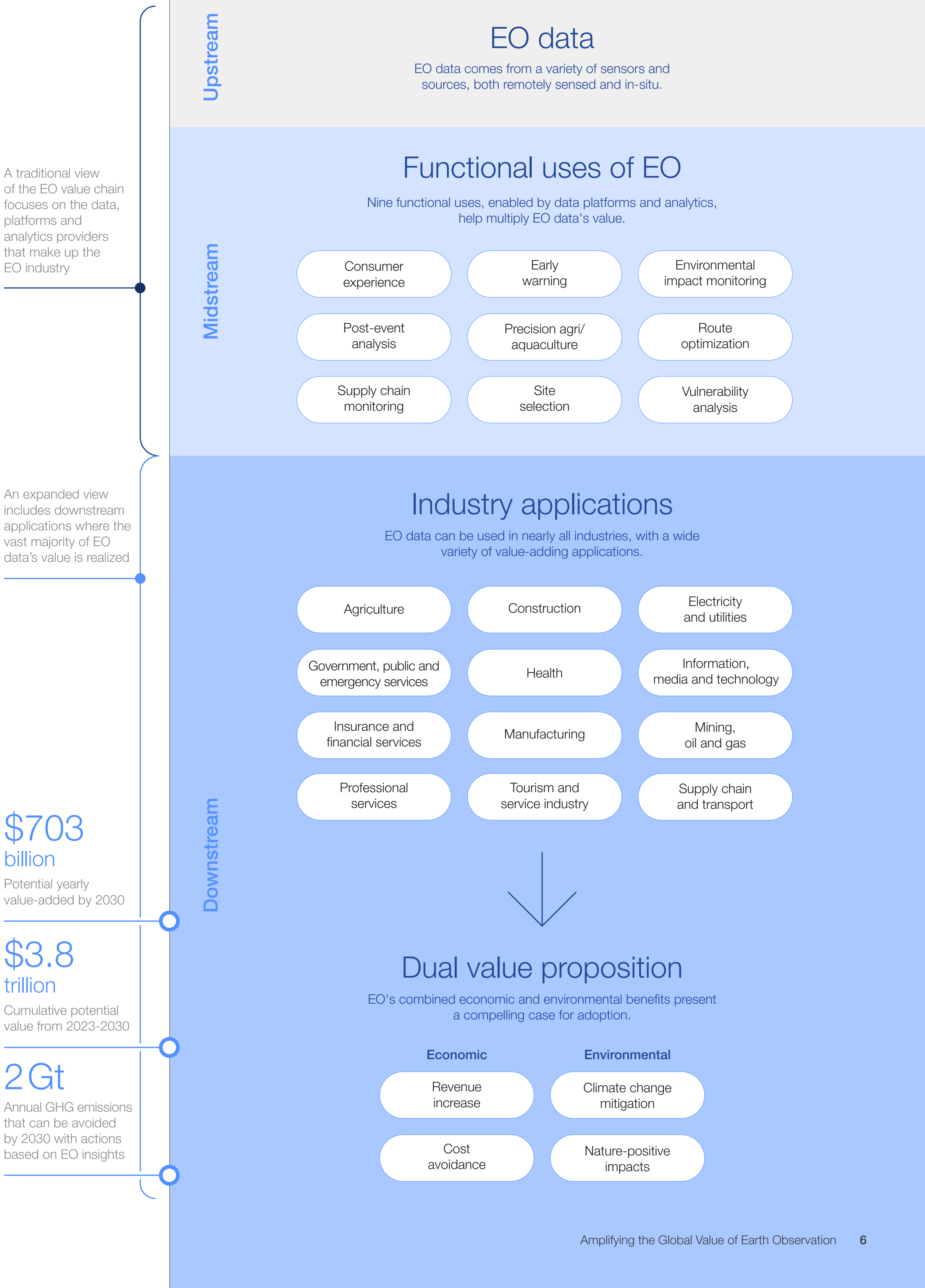
BOX 1

Why 2030?

The period from 2024 to 2030 is a vital window of opportunity to advance EO for climate and nature purposes. Major international commitments linked to the UN Sustainable Development Goals (SDGs), Global Biodiversity Framework, Paris Agreement, Rio Conventions, Dubai Consensus and others culminate in 2030 targets.

Over the same period, environmental disclosure requirements and emissions regulations will take effect, thousands of new EO satellites are forecasted to launch and enabling technologies such as artificial intelligence (AI) may catalyse adoption. As a result, global adoption of EO could increase by 30% or more by 2030, according to a survey of EO industry leaders.

FIGURE 1 **The global EO opportunity**



Upstream

EO data

EO data comes from a variety of sensors and sources, both remotely sensed and in-situ.

A traditional view of the EO value chain focuses on the data, platforms and analytics providers that make up the EO industry

Midstream

Functional uses of EO

Nine functional uses, enabled by data platforms and analytics, help multiply EO data's value.

- Consumer experience
- Early warning
- Environmental impact monitoring
- Post-event analysis
- Precision agri/ aquaculture
- Route optimization
- Supply chain monitoring
- Site selection
- Vulnerability analysis

An expanded view includes downstream applications where the vast majority of EO data's value is realized

Downstream

Industry applications

EO data can be used in nearly all industries, with a wide variety of value-adding applications.

- Agriculture
- Construction
- Electricity and utilities
- Government, public and emergency services
- Health
- Information, media and technology
- Insurance and financial services
- Manufacturing
- Mining, oil and gas
- Professional services
- Tourism and service industry
- Supply chain and transport

Dual value proposition

EO's combined economic and environmental benefits present a compelling case for adoption.

Economic	Environmental
Revenue increase	Climate change mitigation
Cost avoidance	Nature-positive impacts

$703 billion
Potential yearly value-added by 2030

$3.8 trillion
Cumulative potential value from 2023-2030

2 Gt
Annual GHG emissions that can be avoided by 2030 with actions based on EO insights

What is EO?

In July of 1972, the US Department of the Interior launched the first of the satellites that would become the Landsat program. Providing never-before-seen images of the Earth to scientists around the world, Landsat 1 fundamentally changed geographic, cartographic and other Earth science disciplines while also paving the way for satellite-based EO data use in a wide range of other fields.

This study primarily focuses on remote sensing since it is a driving force for scaling EO around the world. In-situ data is considered when it is used to enrich, calibrate or validate remote sensing data or when it cannot be differentiated from it. With daily global coverage, satellites are a key part of that advantage. Nearly everything on the surface of the Earth, and many phenomena above the surface, can be measured with remotely-sensed EO (see Figure 2).

BOX 2

Definitions

EO refers to collecting information about activities and characteristics on Earth, both natural and artificial, including physical, chemical, biological and anthropogenic (human) systems. EO includes both remote sensing technologies and "in-situ" data sources. **Remote sensing** uses a variety of sensors to measure reflected or emitted energy from distant environments. **In-situ** data is collected adjacent to the measuring instrument, like temperature readings by a thermometer. Additional information on the types and attributes of EO data can be found in Appendix 3.

FIGURE 2

Examples of what remote sensing can measure

Remotely-sensed EO can…

- Capture images in the visible spectrum
- Measure the geometry of natural and human made objects (day or night)
- Delineate shorelines and measure soil moisture content
- Assess atmospheric conditions
- Measure temperature and detect heat sources in the infrared spectrum
- Classify land coverage and use including change over time
- Identify and differentiate species of vegetation
- Identify the chemicals present in land, water and atmosphere (including GHGs)
- Classify human made infrastructure and monitor changes over time
- Measure radio, microwave and ultraviolet radiation

In many cases, insights from this data are sufficient to inform data-driven action on their own. Yet, fusing datasets and comparing measurements over time unlocks far more. For example, the ability to analyse a multitude of environmental variables over time makes it possible to forecast weather and measure climate change, while adding socioeconomic data, such as population statistics, can help assess climate impacts on human populations.

Additionally, the internet of things (IoT), mobile phones and other global navigation satellite system (GNSS) enabled devices are rich sources to enhance EO. These sources not only help to calibrate and validate remotely sensed data but also can be fused to improve precision or generate new insights. For example, Waze pioneered the use of crowdsourced GNSS data from consumer devices to improve maps and enable dynamic routing.

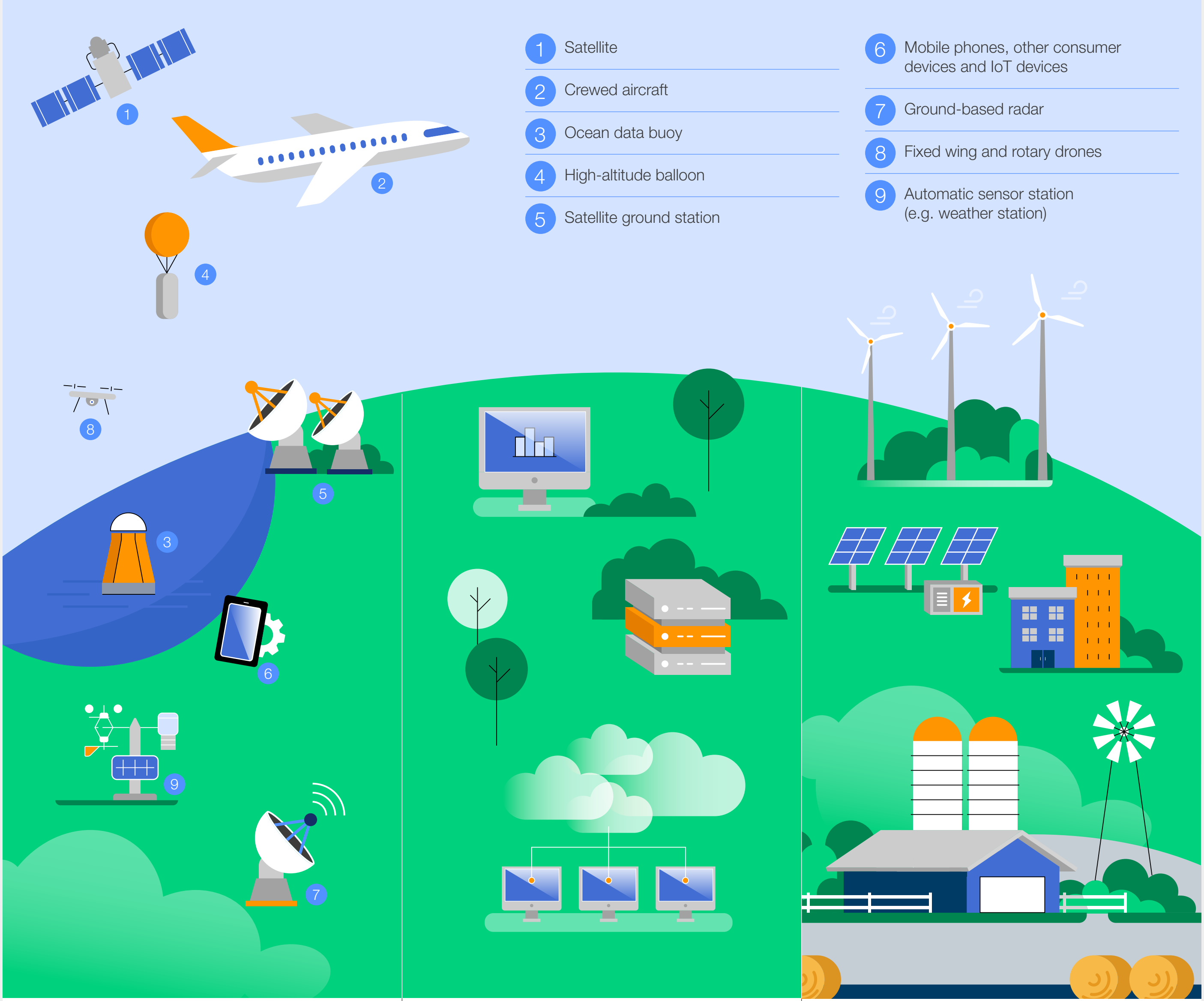
The EO value chain

A basic framework for the EO value chain mirrors the process for generating insights from data, whereby raw data is first collected, then processed to produce useful information, and finally exploited for a variety of end-user applications (see Figure 3).

Across the value chain, a diverse mix of commercial, government, academic and civil society organizations play different roles. Business models vary, with some focusing on narrow industry verticals or niche applications and others providing broad platforms that support a wide range of applications. Integration up and down the value chain is not uncommon, with some data providers operating across upstream and midstream segments and some end users integrating midstream capabilities.

FIGURE 3

Components of the EO value chain



Data acquisition

The EO value chain begins with data acquisition from a variety of sensors and sources. Remotely-sensed data is collected from satellites, piloted aircraft, high-altitude balloons, drones and other platforms. In-situ data is gathered from GPS-enabled devices, IoT sensors and other human-collected or automated measurements in the field.

Data processing and analytics

The midstream segment, data processing and analytics, aims to make vast EO datasets more discoverable, accessible and ultimately actionable. Raw EO data needs to be calibrated, refined, contextualized, curated and fused with other data sources relevant to specific applications.[3]

Data use

The downstream segment of the EO value chain is data use. Unlike depictions of the EO value chain that focus on the EO industry alone, this segmentation captures the role of end users in realizing the full value of EO data and the importance of stimulating downstream use to realize EO's full potential.

How EO data is used

With various types of measurements that can be adapted to specific regions, industries and organizational objectives, the depth and diversity of use cases can be inspiring but may also obfuscate the simplicity of the fundamental value proposition for EO: better data can inform decision-making, optimize solutions and enable innovation.

High level, industry-agnostic categories are helpful to grasp that fundamental value proposition. Each category shown in Figure 4 is framed in terms of the function it serves and comprises a range of unique applications and diverse data sources, across industries. For example, “route optimization” includes particulate matter monitoring, hazardous weather identification, marine surveying and other applications.

These categories are not meant to be exhaustive. Instead, they represent some of the primary ways in which organizations can use EO to create value. Example applications within these categories are detailed in Appendix 2.

Each of the functional use categories has unique applications across several industries. Figure 4 illustrates the relevance and applicability of the nine use categories across major industries.

FIGURE 4 **Current categories of EO data use in downstream applications**

Consumer experience: Providing individual users value through information such as air quality or weather forecasts.

Early warning: Detecting disasters – like floods and wildfires – with more speed and accuracy to bolster planning, response and recovery.

Environmental impact monitoring: Providing a trusted, third-party source to measure environmental impacts and help verify certain environmental commitments and mandates.

Post-event analysis: Analysing environmental changes to better direct emergency response and measure the extent of damages.

Precision agri/aquaculture: Enhancing regenerative practices, reducing input costs and monitoring in-season performance and yield.

Route optimization: Optimizing transport routes in concert with GNSS data by detecting potential environmental disruptions and offering alternatives based on environmental impact.

Site selection: Identifying operational sites for large-scale infrastructure with the best yield, efficiency and/or relative environmental impact.

Supply chain monitoring: Detecting changes to physical goods supply chains and their impacts on international commerce and ecological indicators.

Vulnerability analysis: Characterizing and assessing the risks posed by climate and nature changes and other hazards that may materially impact people, infrastructure and operations.

Industries	Functional use categories								
	Consumer experience	Early warning	Environmental impact monitoring	Post-event analysis	Precision agri/ aquaculture	Route optimization	Site selection	Supply chain monitoring	Vulnerability analysis
Agriculture	◐	●	◐	◐	●	◐	●	●	●
Construction	○	○	●	◐	○	◐	●	◐	●
Electricity and utilities	○	◐	◐	◐	○	◐	●	◐	●
Government, public and emergency services	●	●	●	●	●	●	●	●	●
Health	●	●	◐	●	◐	◐	◐	◐	◐
Information, media and technology	◐	○	●	○	○	○	◐	◐	●
Insurance and financial services	○	◐	●	●	●	○	●	●	●
Manufacturing	◐	○	◐	●	○	○	◐	●	◐
Mining, oil and gas	○	◐	●	●	○	◐	●	◐	●
Professional services	◐	○	◐	◐	○	○	◐	○	◐
Tourism and service industry	●	●	●	◐	○	●	●	◐	◐
Supply chain and transport	●	◐	●	◐	○	●	◐	●	●

● Demonstrated applications ◐ Emerging or plausible applications ○ Limited or no applicability

Note: Common uses of EO in defence, intelligence and other national security applications are not included in this study.

EO market trends and dynamics

Looking back at market studies from the past two decades, it's common to find optimistic outlooks from EO industry insiders. EO's ability to answer an increasing number of vital questions lends itself to a perception that the industry is nearing an inflexion point for growth. Consultations held as part of this study provide an up-to-date perspective on the dynamics influencing the industry's future. Supply- and demand-side dynamics are summarized in Table 1.

The supply-side outlook is largely positive: new EO satellites, advanced sensors and complementary computing capabilities are continuing to push the envelope of what is possible with EO data. However, servicing the potential demand for EO remains a challenge. Key barriers include limited awareness of EO applications, a shortage of specialized talent, fragmented standards, and difficulty navigating the complex EO data and services marketplace. There are likely many reasons these barriers have persisted, including that the commercial EO industry was influenced heavily by government – particularly defence. The business models to enable commercial adoption may look quite different.[4]

Optimism among EO industry professionals persists regarding the role AI can play in driving market growth.[5] Not only are new AI models expected to supercharge the ability to analyse immense catalogues of EO data, but it is also expected to power new ways of interacting with it. If successful, AI-enabled services stand to make EO accessible to non-experts and dramatically lower the demand-side barriers to entry.

> **If successful, AI-enabled services stand to make EO accessible to non-experts and dramatically lower the demand-side barriers to entry.**

TABLE 1

Summary of supply- and demand-side dynamics

Supply-side dynamics: A revolution in EO and supporting technologies is unlocking new possibilities for value-added services

Data acquisition (upstream)	**Commercial competition**	A growing commercial market for satellite-based EO, enabled by lower costs to build and deploy small satellites, is complementing publicly-available data by offering more detail and data types.
	Consolidation and integration	The commercial EO industry has seen consolidation through acquisitions, including vertical integration down the value chain.
	Advancements in EO data quality	New satellites and sensors are improving the range and quality of information available.
Data processing and analytics (midstream)	**Advancements in computing**	Advanced computing, cloud and AI are complementary capabilities that increase efficiency, help extract more information from satellite images and reduce the time from data to insight.
	Value-added services	Additional midstream services are needed to make EO accessible to a wider range of users.

Demand-side dynamics: EO can help meet business and climate imperatives, but its technical complexity and a lack of awareness are holding back demand

Data use (downstream)	**Consumer awareness**	Awareness is increasing in industries with more established use cases but remains a substantial barrier.
	Government-driven market	Spending on commercial EO data is currently dominated by defence and other government agencies, leading suppliers to prioritize them over other industry users.
	Solutions, not pixels	Buying patterns are shifting; new customers are seeking actionable insights rather than raw data.
	The environmental imperative	The growing focus on climate monitoring and disclosures strengthens the relevance of Earth data across sectors.

How the economic and environmental benefits of EO are classified

Downstream applications can offer unique benefits for businesses, governments and civil society. Benefits can be direct, such as the economic gains from using EO to optimize fishery harvests, or indirect, such as the overall health and welfare of the communities that depend on them. This study is focused on the direct benefits shown in Table 2 and quantifies the economic and climate benefits highlighted in Figure 5. While social benefits like public health, security and equity are an integral part of EO's value proposition, they are not a focus of this analysis.

FIGURE 5

Direct economic and climate benefits modelled

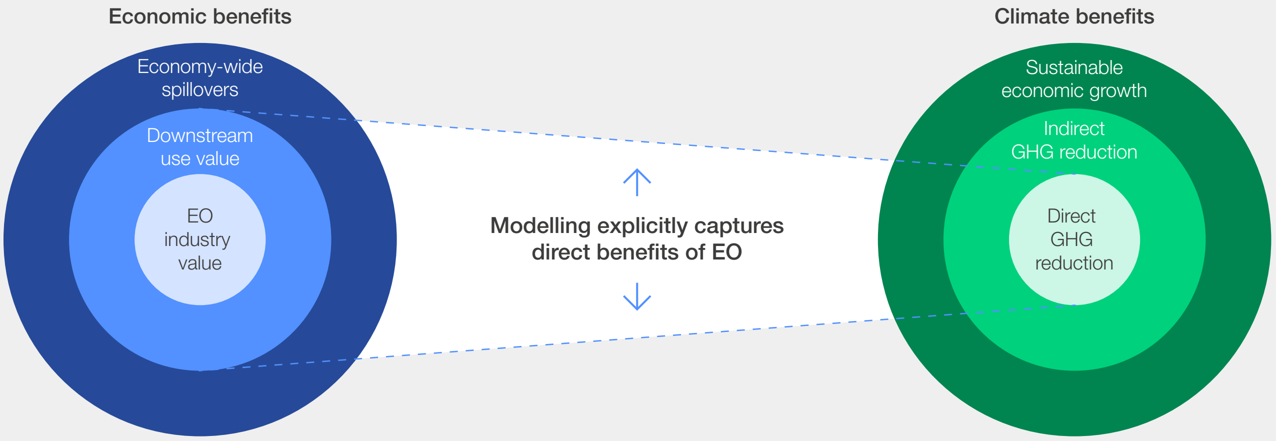


TABLE 2

Direct economic and environmental benefits of EO applications

Category	Type	Description	Unit of measure
Economic	**Productivity (revenue) increase**	– Innovate to create products and services that reach new customers or build new markets. – Increase the output or efficiency of assets and processes. – Increase population health or decrease mortality, thereby supporting per capita economic growth.	Monetary
	Cost avoidance	– Monitor natural hazards to better manage risk posed to infrastructure and operations, mitigating losses. – Comply with regulatory requirements and avoid associated penalties.	Monetary
Environmental	**Climate**	– Monitor climate variables and emissions, which inform actions to mitigate climate change such as limiting GHG emissions and supporting carbon capture.	GHG emissions, expressed in tonnes of carbon dioxide equivalent (CO_2e)
	Nature	– Monitor ecosystems to inform actions that protect and strengthen natural habitats, biodiversity and overall ecological health.	Various ecological metrics (not quantified in this study)

Note: Different GHGs, including carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and others, have varying impacts on global warming. CO_2 equivalent is a measure for various GHGs that is normalized based on their global warming potential (GWP). It is a conversion of the amount of other GHGs to the equivalent amount of CO_2 with the same GWP.

BOX 3

Economic value definition

As used in this study, economic value refers to gross value added. In the context of EO, this is equivalent to the contribution of technology and EO-derived information to gross domestic product (GDP) through increased productivity and avoided costs, such as losses from disasters. Importantly, economic value is not the same as market value, which describes industry revenues or the discounted value of future earnings.

1 The global value of EO data

EO could add $703 billion to the global economy while eliminating 2 gigatonnes of GHG emissions in 2030.

$3.8 trillion

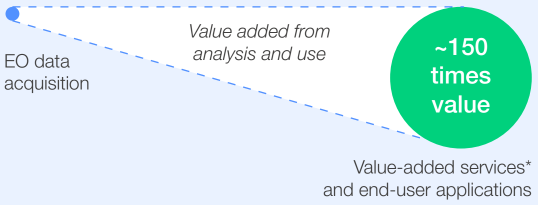
contribution to global GDP between 2023-2030.

For years, the EO industry has struggled to unlock barriers related to technical skills, awareness, policy and more that would fundamentally shift the rate of adoption of EO. The challenge of transforming information to insights and insights into action are not unique to EO; they persistently slow technology adoption, especially in "big data" applications. The potential is evident, and the technical feasibility has been confirmed, but there are not enough people using this technology. The question then arises: what would happen if they did?

The global value of EO data is estimated to be worth $266 billion as of 2023. By 2030, that value could exceed $700 billion, with a cumulative $3.8 trillion contribution to global GDP between 2023-2030. While driving significant economic impact, EO can also inform actions with the **potential to eliminate 2 Gt of GHG emissions every year** while contributing to nature-positive strategies.

BOX 4

Downstream use is the value multiplier



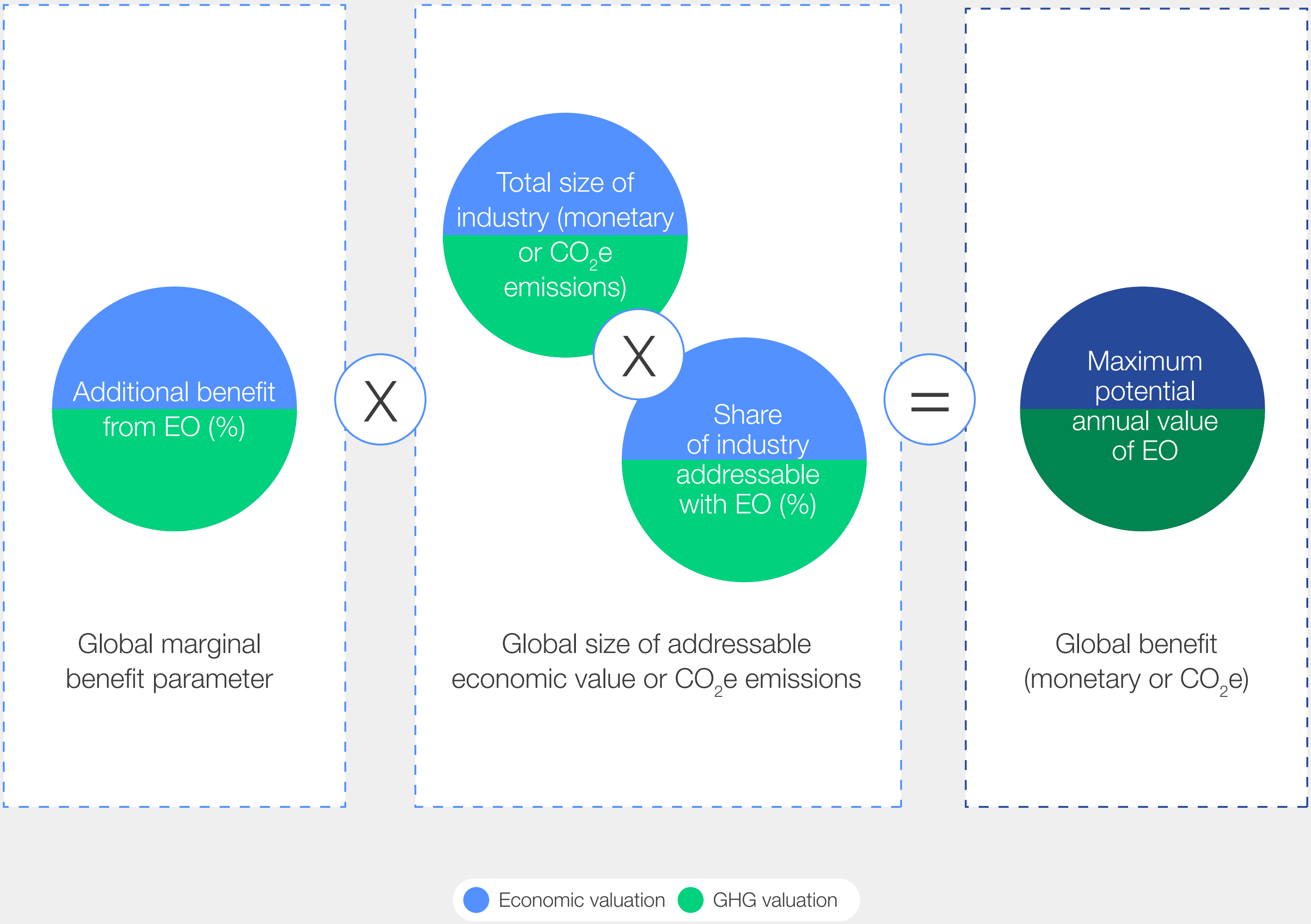
EO is a concentrated industry that enables an outsized impact downstream.

*Value-added services include those provided by organizations considered part of the EO industry.

These figures are the result of a bottom-up examination of the direct economic and climate benefits that can be ascribed to EO through dozens of unique applications and an extrapolation of those benefits across all regions and industries (see Figure 6). The maximum potential value of each EO application is then scaled down based on modelled adoption rates. Refer to Appendix 1 for more details on methodology.

FIGURE 6

How the value of EO applications is estimated



1.1 Economic opportunity in 2030

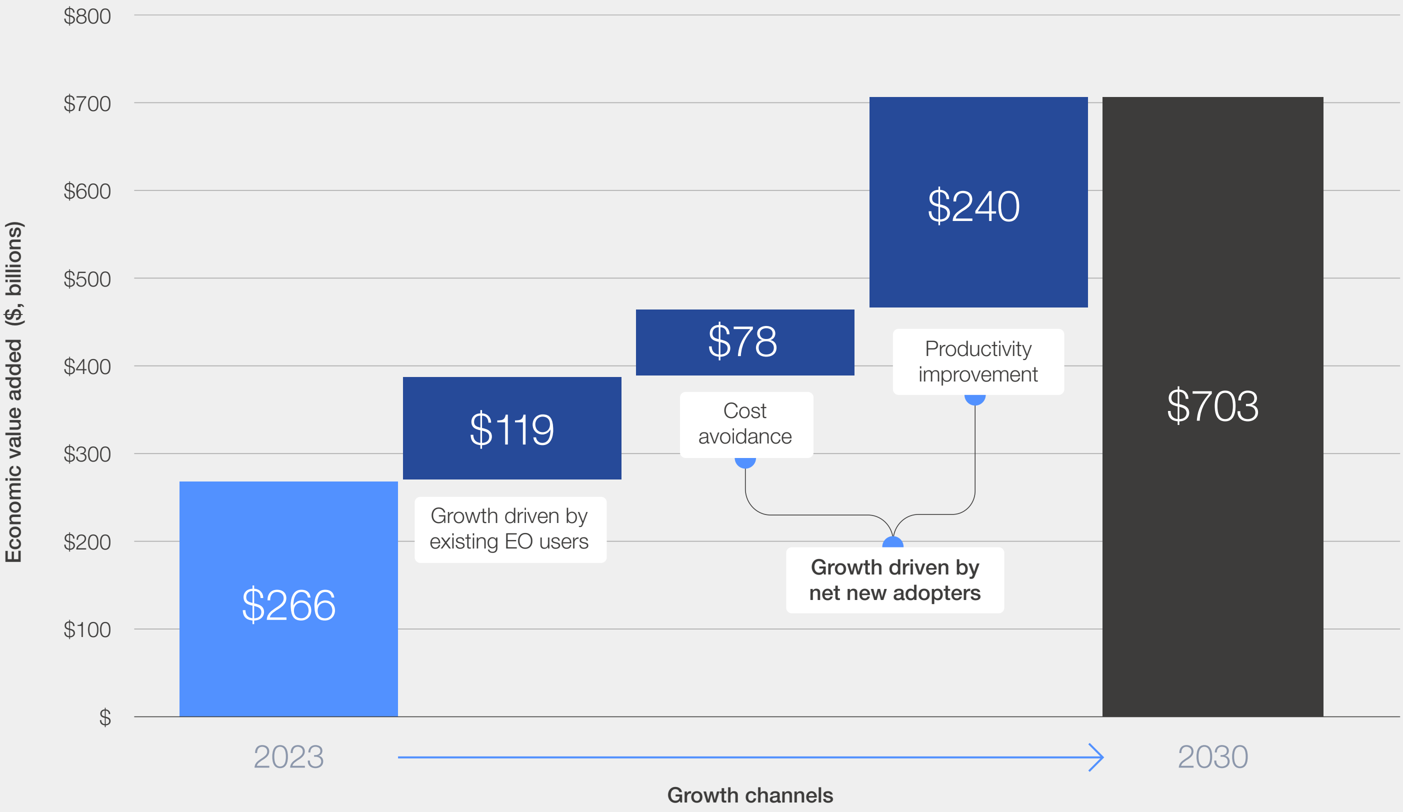
For every 1% increase in downstream user adoption, an additional $9.8 billion in value can be added. Over the modelled period (2023-2030), adoption across the global economy could rise from approximately 39% today to 72% by 2030.[6]

- **$119 billion** driven by existing users of the technology, demonstrating that value will continue to be extracted long after industries first adopt the technology.
- **$78 billion** saved through net-new adoption of EO to manage risk and mitigate losses through applications such as monitoring hazards to critical infrastructure and improving disaster response.
- **$240 billion** gained in productivity through net-new adoption of EO. Private industry is expected to capture most of this value, led by continued global adoption in agriculture, electricity and utilities and insurance and financial services.

The combined economic value of $703 billion is comparable to the GDP of medium-sized economies like those of Belgium ($628 billion) and Taiwan, China ($752 billion) in 2023.[7]

FIGURE 7 **Growth across channels of benefit for EO**

How is value realized?



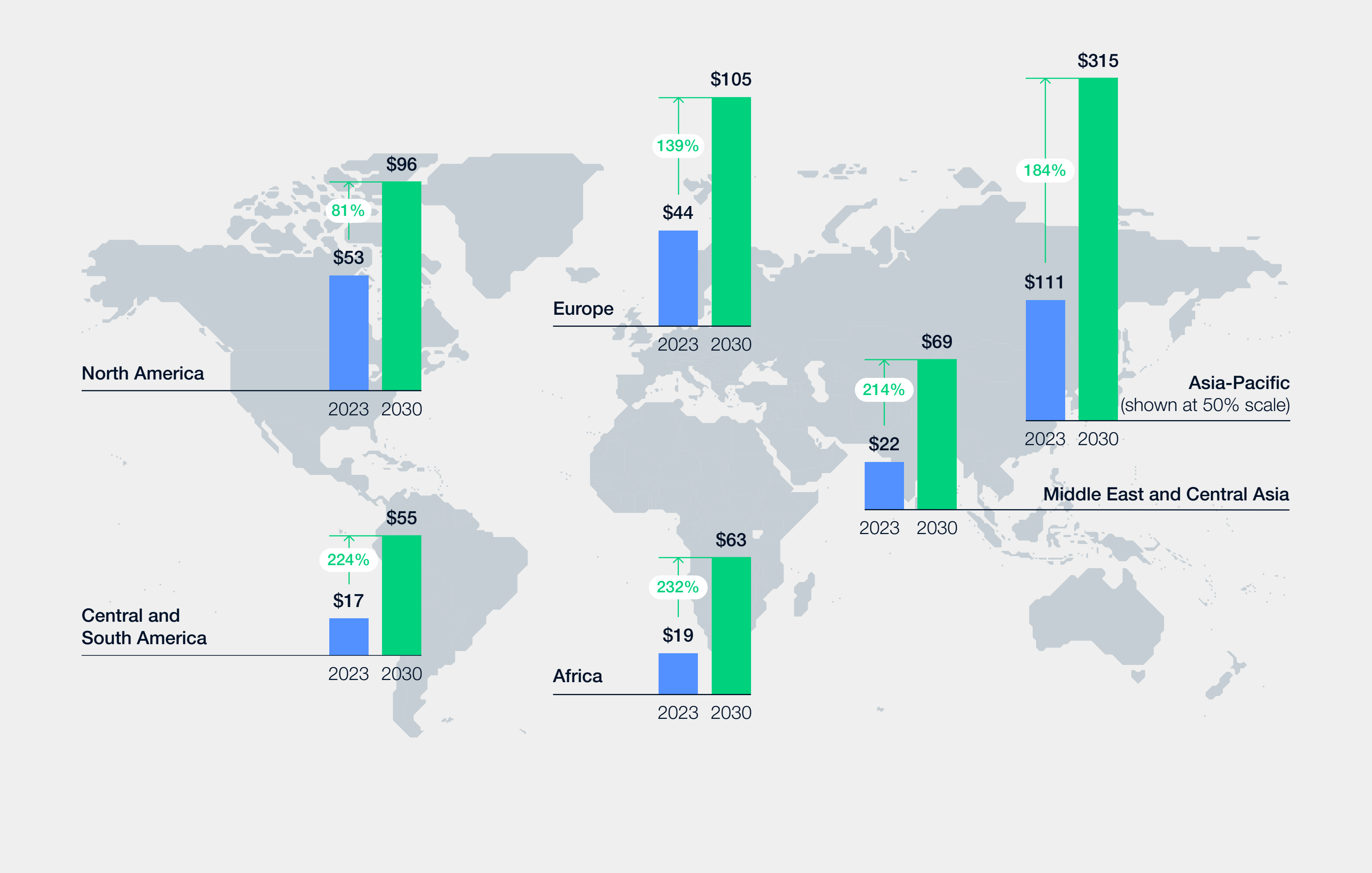
The Asia Pacific region is poised to capture the largest share of EO's value in this period, reaching a potential value of $315 billion.

Regional results

The potential for EO to create value is strongly linked to technology readiness documented at the industry and regional levels. The relative size and future growth profile of those industries in each region also tell a key part of the story.

While North America and Europe are currently global leaders in EO adoption, future growth in these regions is projected to remain steady, while regions with comparatively lower adoption are projected to experience approximately threefold expansion from 2023 to 2030. The Asia Pacific region is poised to capture the largest share of EO's value in this period, reaching a potential value of $315 billion, while Africa and South America are positioned to realize the largest percentage growth. Additional information on adoption modelling can be found in Appendix 1.

FIGURE 8 Regional growth story visualization



By showcasing the immense potential of Earth data in emerging economies, these results underscore the importance of addressing the underlying challenges to scaling. Globally, a lack of resources to build or buy the systems needed to turn EO data into insights and capacity constraints in integrating those insights into operations hinder organizations in using EO data. These challenges are often more pronounced in developing economies. Deriving actionable insights and integrating them into daily operations entails a complex and varied set of "last mile" challenges. Governments and non-profit organizations are actively working to help build capacity and implement locally relevant solutions, but publicly available EO data and open-source solutions are ultimately only a piece of the puzzle.

1.2 The climate and nature opportunity

Economic value generation totalling $44 trillion, which accounts for over half of the world's total GDP, is moderately or highly dependent on nature.[8] Given that relationship, it comes as no surprise that many applications for EO can yield both economic and environmental benefits. Space-based remote sensing is of particular importance as satellites help measure two-thirds of essential climate variables (ECVs) in the UN's Global Climate Observing System (GCOS) plan[9] and provide an effective means to track ecological indicators like vegetation health and changes in land use. Consequently, EO can support 16 of the UN's 17 SDGs (see Figure 9), especially those focused on climate and nature.

FIGURE 9 **SDGs and targets that can be supported by EO**

Goal	Target Contribute to progress on the target, not necessarily the indicator (target numbers represented below)								
No poverty	1.4	1.5							
Zero hunger	2.3	2.4	2.c						
Good health and well-being	3.3	3.4	3.9	3.d					
Quality education									
Gender equality	5.a								
Clean water and sanitation	6.1	**6.3**	6.4	6.5	**6.6**	6.a	6.b		
Affordable and clean energy	**7.2**	7.3	7.a	7.b					
Decent work and economic growth	8.4								
Industry, innovation and infrastructure	9.1	**9.4**	9.5	9.a					
Reduced inequalities	10.6	10.7	10.a						
Sustainable cities and communities	11.2	**11.3**	11.4	**11.5**	**11.6**	11.7	11.b	11.c	
Responsible consumption and production	**12.2**	**12.4**	**12.8**	12.a	12.b				
Climate action	**13.1**	**13.2**	**13.3**	13.b					
Life below water	**14.1**	**14.2**	**14.3**	**14.4**	**14.6**	14.7	14.a		
Life on land	**15.1**	**15.2**	**15.3**	**15.4**	**15.5**	**15.7**	**15.8**	**15.9**	
Peace, justice and strong institutions	16.8								
Partnership for the goals	17.2	17.3	17.6	17.7	17.8	17.9	17.16	17.17	17.18

● SDG targets that can be supported by EO 🟢 Climate and nature-focused SDG targets that can be supported by EO

Source: World Economic Forum, *Unlocking the potential of Earth Observation to address Africa's critical challenges*, 2021.

EO also supports a dual value proposition in many commercial applications. Consider the use of Earth data to inform efficient irrigation (see section 2.1) or monitor supply chain sustainability (see section 3.3); both are examples where businesses can strengthen performance and resilience while benefiting climate and nature. The inverse is also common, whereby using Earth data to demonstrate nature-positive practices can strengthen business performance. For example, both voluntary and mandatory disclosure of environmental impacts can influence a company's position in financial markets and the eyes of their customers (see section 3.1). In this case, an environmental impact monitoring application yields **direct environmental** benefits that translate to **indirect economic** benefits captured through other applications like vulnerability analysis and supply chain monitoring.

BOX 5 **The scale of EO's dual value applications**

In 2030, approximately $550 billion in economic value associated with downstream uses of EO is tied to applications with corresponding benefits for climate and nature. This represents nearly 80% of the total global value-added by the technology in that time.

The climate value of EO

As shown in Table 2, EO's direct benefits for climate stem from informing actions to mitigate GHG emissions and support carbon capture. This study revealed that mitigations informed by EO data applications have the potential to reduce over 2 billion tonnes of CO_2e annually by 2030. This equates to 3.8% of the global annual GHG emissions today.[10] Table 3 lists the five applications with direct climate benefits which were modelled, totalling 2 Gt of CO_2e and representing a portion of the potential benefit.

TABLE 3 **Modelled EO applications with direct climate benefits**

Use category	Example application	How dual value is realized	GHG reduction possible in 2030
Early warning	EO can be used to better characterize wildfire risk and to spot wildfires faster. Following the Australian bushfires in 2020, which cost an estimated 30 lives and devastated an area equivalent to the United Kingdom, researchers estimated that early warnings could reduce the area of land affected by up to 16%.[11]	Economic benefits from avoiding property damage alone are significant. In addition to preserving lives, livelihoods and natural ecosystems, preventing or extinguishing fires before they spread can greatly limit the amount of CO_2 released from combustion.[12]	**64 million tonnes (Mt) CO_2e**
Environmental impact monitoring	Satellites and aircraft-borne sensors can monitor GHGs like CO_2 and methane. The increasing precision of these platforms has been demonstrated to pinpoint emissions sources like oil and gas pipeline leaks.	Fixing leaks means saving product and capturing incentives. The International Energy Agency estimates that oil and gas companies can reduce almost 45% of methane emissions from oil and gas operations at no net cost.[13]	**1,700 Mt CO_2e**
Route optimization	In conjunction with GNSS technology, EO can be used to dynamically plan and optimize shipping routes. For example, the Finnish Meteorological Office uses data from the EU's Copernicus programme to help ships navigate icy seas.[14]	Increased route efficiency means shipping companies can lower fuel consumption by up to 3%,[15] resulting in reduced costs and direct abatement of GHG emissions.	**15 Mt CO_2e**
Precision agriculture	In a cropping context, using overhead imagery to monitor plant health can be used to infer information about nutrient uptake from soil. In turn, that information can inform variable rate application (VRA) of fertilizers, water and other inputs.	VRA of fertilizer has been shown to reduce the cost of inputs by as much as 25% while increasing crop yield by 2.5%.[16] Limiting fertilizer directly abates GHG emissions from nitrous oxide (N_2O), which has 273 times the warming potential of CO_2 by mass.[17]	**27 Mt CO_2e**
Supply chain monitoring	EO has been used as an effective tool to detect illegal deforestation and inform action to stop or slow it.[18]	Slowing deforestation can avoid direct carbon emissions and maintain carbon sinks while helping businesses to avoid fines and strengthen their position in sustainable finance markets.	**216 Mt CO_2e**
Total			**2 Gt CO_2e**

All these benefits relate to climate change mitigation, but EO is also beneficial for climate adaptation. Namely, EO can inform pathways and provide the data needed to assess business cases for adaptation. In turn, EO can be a valuable tool to help businesses and governments avoid losses and prosper through changing environmental conditions. The benefits of adaptation are largely realized as economic gains and are captured in the potential $703 billion value of EO by 2030.

CASE STUDY 1

MethaneSAT

The ability to track global methane emissions is one of the most promising dual-value applications to emerge over recent years, offering actionable data to help reduce emissions of a potent greenhouse gas while increasing operational efficiency.

Methane accounts for about 16% of global emissions, trailing only CO_2.[19] However, it is considerably more potent than CO_2, creating 80 times the 20-year warming effect in the atmosphere.[20] As such, targeted efforts to reduce methane emissions are expected to significantly curb global warming.[21]

To support this endeavour, MethaneSAT, a wholly owned subsidiary of the non-profit Environmental Defense Fund (EDF), worked with BAE Systems (formerly Ball Aerospace)' Space & Mission Systems to develop MethaneSAT. This satellite combines high spatial resolution imagery and a wide field of view to provide unprecedented precision in identifying and tracking methane emissions sources. Data from MethaneSAT will be published free of charge, enabling fast data turnaround and actionable intelligence through analyses on platforms such as Google Earth Engine. Once these data are analysed, the results will provide regulators, industry leaders, lawmakers and the public with the information needed to motivate and enable action to curb emissions.

The energy sector accounts for about 40% of human-caused methane emissions, the second leading contributor globally.[22] Methane leaks also cost the industry an estimated $2 billion in lost revenue annually in the US alone.[23] According to Shell, "Virtually eliminating methane emissions from our operations by 2030 is a priority" and "standardized and consistent measurement-based quantification is of utmost importance for the industry to increase accuracy and transparency on reported emissions".[24] By providing a means to find and fix leaks quickly, MethaneSAT will enable cost-effective mitigation actions while making major strides to combat climate change.

MethaneSAT launched in March 2024, aiming to support reductions in methane emissions from the oil and gas industry by 45% by 2025 and 70% by 2030.[25] As its data becomes available, MethaneSAT will augment the capabilities of a rapidly maturing global ecosystem of organizations with complementary goals to stem methane emissions, including aeroplane- and satellite-based EO platforms like Insight M and GHGSat, respectively, as well as analytics firms like Kayrros using this data to provide environmental intelligence and insights.[26]

EO benefits for nature-based solutions

Organizations around the world are becoming increasingly aware of the importance of healthy ecosystems and biodiversity to ensure a resilient and sustainable future. To manage impacts and dependencies on nature, they must be measured. EO's benefits for nature, therefore, derive from the ability to measure a range of important factors like biomass, plant leaf chemistry, water quality and grazing patterns. With sufficient scale and revisit rates, these measurements can also serve as proxies for overall ecosystem health.

Together, these measurements provide a foundation for alignment on what steps organizations can take to address their impacts and dependencies on nature. The Taskforce for Nature Related Financial Disclosures (TNFD) and the Science Based Targets for Nature (SBTN) guidance aims to do just that. Through these means, organizations can use EO to monitor and protect biodiversity, design nature-positive solutions, open the door to new nature-driven markets and more (see Table 4).

> **[SBTN] guidance will ensure that businesses are acting in line with science and ensure that any nature-based solutions they are considering alongside their emissions reduction efforts are implemented in a way that maximizes the benefits for nature, communities and climate.**
>
> Johan Rockström, Director, Potsdam Institute for Climate Impact Research[27]

TABLE 4 **Example EO applications with positive nature benefits**

Use category	Example application	How dual value is realized
Vulnerability analysis	Satellite-based remote sensing can detect the loss of valuable mangroves by tracking changes in erosion rates along coastlines. Spotting losses early can help inform timely action for protection, recovery and restoration.	Mangroves are among the most valuable ecosystems in the world, supporting tourism, purifying water and serving as fisheries for valuable foods like crabs and shrimp.[28] They also help prevent more than $57 billion in flood damage globally each year[29] and function as significant carbon sinks.
Environmental impact monitoring	EO has proven to be an effective tool in supporting coral reef ecosystems. Tools like 3D maps of the Great Barrier Reef are used to target sites for restoration efforts by foundations, governments and commercial companies.[30]	The Great Barrier Reef is the home of hundreds of thousands of species and contributes almost $5 billion to the Australian economy each year.[31]

Dual nature and economic value can also be seen in the emergence of nature-related disclosures for financial markets. The Taskforce on Nature-related Financial Disclosures (TNFD) – a framework focused on governance and underpinned by measurable metrics – is a direct answer to the call from consumers and investors for more transparency around climate and nature impacts. While both may seek to avoid supporting companies that negatively impact nature, investors and other financial entities also see biodiversity loss as a material risk to their bottom line.

2 Industries with the most value to gain

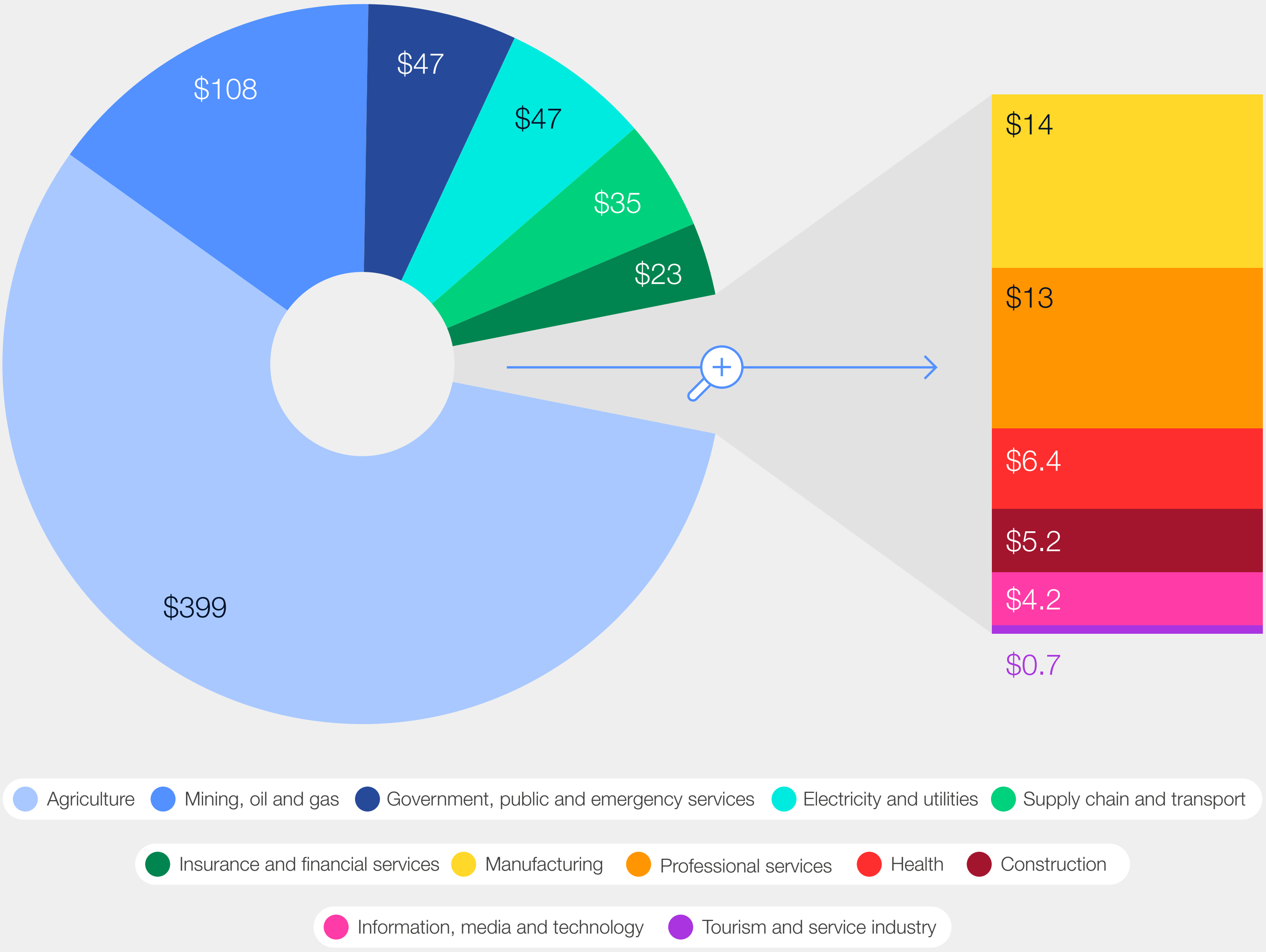
Six industries stand to capture 94% of the projected economic value.

Early waves of EO adoption most benefited tech-ready industries such as insurance, financial services, mining, oil and gas, which were able to uncover novel insights for decision-making. Industries such as agriculture, government, electricity, utilities, supply chain and transport are expected to capture the lion's share of value over time, in line with their propensity to adopt technologies later.

The potential economic value added from EO to each industry is illustrated in Figure 10, 94% of which is expected to be driven by applications in the six key industries highlighted in the sections to follow.

Within each industry, example EO applications that provide economic and climate value are highlighted, with those included in modelling efforts tagged accordingly. For more information on the modelled applications, please refer to Appendix 1.

FIGURE 10 **Potential global economic value from EO data by 2030 ($, billions)**



2.1 Agriculture

Modern agricultural practices increasingly rely on EO data. In technologically advanced farming operations, EO plays a vital role in daily operations, from guiding the optimal application rates of fertilizers and water to increasing the accuracy of yield estimates. Agricultural EO applications represent a nearly $400 billion economic opportunity in 2030.

Even as EO data and services become more readily available, usable and affordable, infusing this technology in an industry that is typically slower to adopt new technology can present challenges. Traditional operations benefit from integrating remote sensing and in-situ data sources to provide cost-effective, localized insights and find strategies to deploy them at scale.

Dual value: The use of EO in agriculture exemplifies how data-driven decisions to reduce consumption to simultaneously benefit the environment and the bottom line. For example, studies have shown that fertilizer inputs can be cut by 4-6% overall when using EO for precision agriculture,[32] allowing farmers to cut costs while also reducing GHG emissions from fertilizers. EO-enabled, targeted water and pesticide applications can further limit harmful effects on ecosystems and biodiversity. EO can also be used to independently verify carbon sequestration and other sustainable agriculture and aquaculture practices.

FIGURE 11

Key findings

Agriculture could capture **more than 50% of the economic** value from EO in 2030.

85% of that value is driven by productivity-enhancing **precision agriculture.**

Precision agriculture can help **eliminate 27 million tonnes (Mt) of GHG emissions** per year.

TABLE 5

Table 5: Example EO applications

Use category	Example application	How dual value is realized
Precision agri/aquaculture	✱ ⊕ Cropping	Ⓟ Gives farmers access to higher quality information about plant health that can improve decision-making for variable rate application of inputs like fertilizers and water, leading to higher crop output
	✱ Fishery management	Ⓟ Provides information on water quality and fish stocks to inform optimal aquaculture site management and harvesting
	✱ Livestock management	Ⓟ Helps farmers manage livestock more effectively, by enhancing grazing decisions and unlocking targeted interventions to increase pasture biomass
	✱ Timber harvesting	Ⓟ Optimizes the timing and amounts of harvesting by providing key indicators of vegetation health
Early warning	✱ Wildfire detection	Ⓒ Improves wildfire suppression responses with better characterization of the risk they will occur and earlier detection when they do
	Famine forecasting	Ⓒ Supports early identification of shortages in important crops like corn and wheat to inform mitigating action by governments or non-profits
Vulnerability analysis	✱ Seasonal weather forecasting	Ⓒ Enables data-driven decisions such as when to plant and harvest certain crops or when watering is needed, based on climate and weather forecasts
	Access to finance	Ⓟ Uses satellite imagery and location intelligence to de-risk loans that finance essential cropping inputs
Supply chain monitoring	✱ Sustainable forestry	Ⓒ Provides traceability of timber, helping to enable compliance with sustainable forestry regulations

✱ Included in economic valuation ⊕ Included in GHG valuation Ⓟ Productivity increase Ⓒ Cost avoidance

2.2 Electricity and utilities

Early adopters of EO in the electricity and utilities industry have gained an information advantage that extends from generation site selection to demand-side management. Utilities providers can also benefit by using EO to assess vulnerabilities in large-scale infrastructure like pipelines and power grids. For example, electric utility provider Southern California Edison uses EO for wildfire risk management, identifying at-risk assets in regions susceptible to wildfire through the fusion of EO data with machine learning algorithms.[33]

Dual value: In the electricity and utilities industry, EO can be used to improve the quantity and quality of data that inform site selection and operations management for renewables projects. Forecasting the energy potential for new solar, wind and hydropower sites expected as part of the proliferation of renewable energy this decade can help improve the return on investment of projects by increasing system performance and optimizing energy trading strategies.[34] As such, EO's dual value proposition for electricity and utilities could accelerate the energy transition while enabling over $47 billion in economic value.

FIGURE 12

Key findings

Electricity and utilities could become the fourth largest beneficiary of EO in 2030 with a **$47 billion boost in productivity.**

APAC can lead in growth, capturing 52% of the value added in 2030 due to the region's high investments in renewables.

Indirect climate benefits stem from **renewables planning and optimization.**

TABLE 6

Example EO applications

Use category	Example application	How EO adds value
Site selection	✳ Clean energy planning	Ⓟ Identifies optimal locations for clean energy assets (pumped hydro, solar, wind, transmission) through both historical and projected environmental impact measurements
Early warning	✳ Energy demand forecasting	Ⓟ Informs weather forecasts and climate models that can be used to forecast heating and cooling demand, helping to optimize energy supply and reserves
	✳ Energy output forecasting	Ⓟ Supports short-term forecasting that enables loans planning and trading strategies based on renewable energy generation from wind, solar and tidal sources
Vulnerability analysis	✳ Network condition monitoring	Ⓒ Informs modelling of the long-term structural integrity of large-scale energy infrastructure, such as power lines or solar plants, to characterize risks from environmental hazards like land subsidence or vegetation encroachment
	✳ Severe weather modelling	Ⓒ Forecasts severe-weather events that may impact the reliability and availability of electricity networks or lead to failures in critical infrastructure such as dams, allowing for mitigation strategies to be put into place

✳ Included in economic valuation ⊕ Included in GHG valuation Ⓟ Productivity increase Ⓒ Cost avoidance

2.3 Government, public and emergency services

The EO data story, especially as it relates to satellite-based remote sensing, began with governments. As a result, the adoption of EO data in governments with well-established space programmes, like the US, the EU, Japan and others, is robust. These countries have broad applications in downstream uses from emergency management to urban planning and much more. Today, both legacy and newly established government EO programmes are not only deploying new satellites but also buying EO data from commercial providers. As such, government applications of EO are expected to see significant continued growth in adoption.

Dual value: EO is anticipated to generate a significant double dividend as it relates to disaster mitigation and response. Timely situational awareness can help avoid substantial capital losses while simultaneously mitigating environmental impacts. Environmental benefits can include avoiding biodiversity losses and GHG emissions from wildfires or reducing harmful impacts to vegetation, water quality and ecosystems from floods. Proactive monitoring of high-risk areas through EO allows resources to be deployed quickly for emergency management and disaster response teams to achieve their missions. For example, a study of near real-time routing for emergency services could significantly shorten average response times in the flood-prone Lower Mekong River Basin. The result of using EO data in this case could not only save lives but also millions of dollars annually.[35]

FIGURE 13

Key findings

Established applications continue growing towards a potential **$47 billion value in 2030.**

Deterring illegal activities and **enabling emergency management** are primary drivers of value.

Early warning for wildfires can help **eliminate 64 Mt of GHG emissions** per year.

TABLE 7

Example EO applications

Use category	Example application	How EO adds value
Supply chain monitoring	⊛ Illicit activity monitoring and enforcement	Ⓟ Monitors land use, water use and infrastructure changes over time using optical and radar data to detect illegal extraction (e.g. mining, fishing) and trafficking
Post-event analysis	⊛ Disaster response management	Ⓒ Provides near real-time updates on changes (or damage) to structures, land and vegetation, allowing for a more cost-effective response
Vulnerability analysis	⊛ Transport infrastructure monitoring	Ⓒ Improves surveying methods that can be used to model degradation to roads and other infrastructure, thereby improving preventive maintenance
Site selection	⊛ Sustainable urban planning	Ⓟ Enables monitoring of indicators like air quality and land use in human settlements to help select locations for housing, transport and public spaces
Early warning	⊛ ⊕ Hazards monitoring	Ⓒ Assesses the risks posed by environmental hazards such as floods, droughts, forest fires, landslides and tsunamis and enables early detection of the signatures associated with the onset of disasters

⊛ Included in economic valuation ⊕ Included in GHG valuation Ⓟ Productivity increase Ⓒ Cost avoidance

2.4 Insurance and financial services

Insurance companies and financial institutions have used EO to estimate potential losses in the wake of a disaster for over a decade, with human analysts interpreting data and estimating costs. More recently, the emergence of automated services has led to rapid growth in EO applications in both insurance and financial services industries, given their relative propensity to adopt new technologies quickly. Insurance companies capture much of this value by using EO data to better assess risk, offer parametric insurance products and find efficiencies in assessing claims. In financial services, EO provides accuracy and traceability for key metrics related to commodity sourcing, sustainable operations and exposure to physical risks from climate change and more, enabling data-driven decisions for investment and lending.

Dual value: Biodiversity loss and climate change pose material physical and transition risks to assets under management by the financial services and insurance industries. EO data can help better understand and mitigate environmental risks, both through measurement and verification and through adapting investment decisions to favour environmentally sustainable assets.

FIGURE 14

Key findings

Extreme weather and disaster risk mitigation contributes **$23 billion to EO's economic opportunity by 2030.**

Digitally intensive and tech-ready, the industry may experience **three-fold growth in the value of EO from 2023 to 2030.**

Sustainable finance can drive **substantial indirect climate benefits.**

TABLE 8

Example EO applications

Use category	Example application	How EO adds value
Supply chain monitoring	✱ Market efficiency for commodities trading	Ⓟ Provides timely data on economic indicators such as global shipping volumes, manufacturing output (e.g. cars leaving manufacturing facilities) and proxies for retail performance which support accurate pricing of assets in financial services
	✱ Sustainable finance (verification)	Ⓒ Monitors production and operations to support verification of sustainability metrics such as ethical sourcing claims that are tied to financial reporting requirements or energy transition investments
Vulnerability analysis	✱ Sustainable finance (investment analysis)	Ⓒ Enables objective and reproducible analyses to model and manage exposure of financial investments to environmental related risks
	✱ Insurance premium calculation	Ⓟ Supports assessment of asset value and relevant hazards (such as the proximity of trees or swimming pools for homeowners' insurance) to calculate appropriate coverage and premiums more efficiently
	✱ Credit risk modelling	Ⓒ Forecasts revenue based on production trends and yield modelling, thereby providing a cost-effective means to assess credit worthiness (such as for rural farmers)

✱ Included in economic valuation ⊕ Included in GHG valuation Ⓟ Productivity increase Ⓒ Cost avoidance

2.5 Mining, oil and gas

The applications of EO in mining, oil and gas start upstream in the industry, with insights to support cost-effective extraction and extend to reliable and efficient distribution, storage and downstream operations. As a result, the industry is seen as a top adopter of EO technologies, with a modelled adoption rate near 60% in 2023.

Satellite imagery can help identify areas with the highest mineral resource potential in a more cost-efficient manner than traditional methods, especially in remote regions. Additionally, EO measurements can provide near real-time information on leaks and emissions, allowing organizations to prioritize fixes that limit both production losses and environmental damage.

Dual value: The dual value of EO in detecting and mitigating GHG emissions from oil and gas is explored in section 1.2. Additionally, in the mining industry, studies are under way to use hyperspectral imaging to search for rare Earth minerals left behind in old mines[36] and to combine data from space-based remote sensors with in-situ sources to enhance lithium exploration.[37] These techniques, if successfully scaled, may accelerate the pipeline of critical minerals projects that are crucial to supply a range of technologies needed in the energy transition, such as electric vehicles and wind turbines.

FIGURE 15

Key findings

As a mature EO user, the industry derives the second largest share of value from EO, a **$108 billion opportunity in 2030.**

EO can support **resource exploration,** help optimize **capital-intensive** operations and reduce risk to **infrastructure.**

Detecting and mitigating emissions with EO can help **eliminate 1.7 Gt of GHG emissions** per year.

TABLE 9

Example EO applications

Use category	Example application	How EO adds value
Site selection	✳ Resource exploration	Ⓟ Improves resource exploration accuracy for new mineral extraction sites (especially in remote areas) and for assessing resources remaining in old mines, leading to higher extraction volumes
Early warning	Tailings dam monitoring	Ⓒ Detects ground movement to predict potential failures of the tailings dams that are used to collect potentially toxic by-products of mining, enabling preventive maintenance
	Extraction operations	Ⓟ Supports safety and efficiency by monitoring and forecasting environmental conditions that may impact extraction operations and logistics
Environmental impact monitoring	Pollution monitoring	Ⓒ Monitors activities within extraction areas and waste sites to detect pollution and support remediation both during and after operations at the site
Vulnerability analysis	✳ ⊕ Pipeline monitoring	Ⓒ Monitors pipeline condition using specialized sensors to measure change over time and environmental readings to determine potential leakages
	✳ Weather forecasting	Ⓒ Improves long-term planning to minimize project delays and forecasts short-term weather events to mitigate potential damages

✳ Included in economic valuation ⊕ Included in GHG valuation Ⓟ Productivity increase Ⓒ Cost avoidance

2.6 Supply chain and transport

Most long-range transport methods have long relied on EO-enabled weather information to effectively plan routes and are now integrating additional EO-enabled insights for route optimization, like measuring particulate matter in air routes or sea ice levels for ship routes. EO also provides traceable supply chain insights for an increasing number of companies focused on ethical sourcing. Not only can companies track physical goods within their own supply chain operations, but also upstream in the supply chains of their vendors.

Dual value: As environmentally conscious consumers exert pressure on markets to ethically source products, organizations differentiate with verified proof of origin traceable with EO intelligence. Research shows that as much as a 10-15% price premium may be levied for sustainably sourced commodities.[38,39] For example, Satellogic (among other providers) uses satellite data to help demonstrate “deforestation-free” cocoa harvested in West Africa.[40]

FIGURE 16

Key findings

EO’s value could grow **from $14 billion in 2023 to $35 billion in 2030,** driven by route optimization and supply chain monitoring.

Using EO to **improve freight routes** could drive efficiency gains of $9 billion to the industry in 2030 alone.

Optimising shipping routes could help **reduce 15 Mt of GHG emissions** per year.

TABLE 10

Example EO applications

Use category	Example application	How EO adds value
Environmental impact monitoring	Shipping emissions	Ⓒ Detects pollutants emitted from ships, such as airborne emissions that manifest in artificial clouds (ship tracks), helping to monitor and enforce emissions regulations
Route optimization	✳ ⊕ Ship route optimization	Ⓟ Enables dynamic route planning through the near real-time monitoring of water depth, winds, waves, currents and sea ice conditions, allowing ships to shorten routes
	Plane route optimization	Ⓟ Predicts and monitors air conditions and hazards from weather and other events (e.g. volcanic eruptions), which enables near-real-time adjustments to routes
	✳ Traffic congestion monitoring	Ⓟ Monitors traffic conditions in real time and informs drivers of alternatives, thereby optimizing time
Supply chain monitoring	✳ Proof of origin	Ⓟ Enables accurate and verifiable tracing of globally traded goods, enhancing supply chain resilience
Vulnerability analysis	✳ Seasonal weather information	Ⓒ Forecasts adverse weather conditions to improve safety of all modes of transport

✳ Included in economic valuation ⊕ Included in GHG valuation Ⓟ Productivity increase Ⓒ Cost avoidance

3

Cross-industry uses of EO to amplify climate and nature impact

Harnessing the dual value of EO in three high-impact uses can accelerate market growth and drive measurable progress towards climate and nature goals by 2030.

> **A majority (over 80%) of identified potential GHG emissions reduction from the use of EO can be tied to EO-enabled environmental impact monitoring.**

As explored in chapters 1 and 2, EO can contribute to planetary well-being through a wide variety of applications. Activating the economic co-benefits of dual value applications is a promising mechanism to capture yet untapped value. Among dual-value applications, those with the greatest potential to accelerate global impact are both feasible and scalable:

Feasibility

- **Technical feasibility**: Enabling technologies, like specific sensors and analytics capabilities (e.g. AI and cloud computing), are mature and widely available or will be in the coming years.
- **Operational feasibility**: The implementing organization has the capability and direct influence to achieve its intended outcomes.
- **Economic feasibility**: Returns – financial or otherwise – outweigh incremental costs and are sufficient to close the business case.

Scalability

- **Organizational scalability**: The value proposition is not highly dependent on organization-specific capabilities or business models that would present barriers to entry.
- **Cross-region scalability**: Applications are extensible to different regions and geographic scales (i.e. local, regional or global), and regional differences do not significantly hinder the adaptation of EO applications to new locations.
- **Cross-industry scalability**: The value proposition is relevant and attainable across multiple industries.

When coupling these feasibility and scalability considerations with the corresponding economic, climate and nature value modelled in this study, the following use categories stand out as highly promising:

1. Environmental impact monitoring

All identified industry groups have at least an emerging application for environmental impact monitoring, with over 50% having a demonstrated application.

A majority (over 80%) of identified potential GHG emissions reduction from the use of EO can be tied to EO-enabled environmental impact monitoring.

2. Vulnerability analysis

Over 60% of industry groups have a demonstrated application for vulnerability analysis in the market, with all industries having at least an emerging application.

By 2030, EO-enabled vulnerability analysis could support $138 billion in economic value, and all modelled applications have the potential to create positive downstream environmental impacts.

3. Supply chain monitoring

Over 90% of industry groups have a type of supply chain monitoring application, with over 40% having a demonstrated application in the market today.

The use of EO for supply chain monitoring could generate upwards of $60 billion in economic value in 2030, and all modelled applications have the potential to create positive downstream environmental impacts.

3.1 Environmental impact monitoring and disclosure

> **There is still a need for collaboration across the EO industry to define shared standards fulfilling regional and global environmental commitments and frameworks.**

Growing public awareness of climate change and environmental degradation has spurred a global push for monitoring and accountability. Environmental, social and governance (ESG) standards are rapidly evolving from elective to directive and varying in geographic applicability. A few of the recent and noteworthy actions influencing environmental impact monitoring and disclosure practices include:

- In the EU, the Corporate Sustainability Reporting Directive (CSRD) mandates climate disclosures for companies listed on EU-regulated markets beginning in 2024.[41] Separately, the EU Deforestation Regulation (EUDR) will take effect in December 2024 and will require reporting on the provenance of commodities.[42]
- Regulation approved by the US Securities and Exchange Commission (SEC) in March 2024 will require reporting of climate-related disclosures, including governance of climate-related risks, the impact of climate-related physical and transition risks, and scope 1 and 2 GHGs.[43]
- Frameworks developed by the Task Force for Nature-Related Financial Disclosures (TNFD) and the Task Force for Climate-Related Financial Disclosures (TCFD) are intended to improve the alignment and interoperability of global standards. In 2023, the International Sustainability Standards Board (ISSB) incorporated TCFD recommendations into its first two standards, which it will use to monitor companies' progress.[44]

In addition to satisfying increasing reporting requirements, showcasing the impact of environmental initiatives can provide financial benefits in an increasingly environmentally conscious world. After all, over 85% of investors considered ESG factors in their investments in 2020,[45] and a 10% improvement in company-level ESG performance indicators correlates with an approximate 1.8 times higher market value (measured by EV/EBITDA[46] multiple).[47] This signals that environmentally sustainable business practices will not only reshape investment decisions but also tie to overall business performance. As a result, over 40% of Standard and Poor's (S&P) 500 companies now **voluntarily** address some aspect of sustainability in financial filings.[48]

For both mandatory and voluntary disclosures, having ready access to objective, repeatable and near-real-time data is key. In principle, EO can provide just that. However, environmental standards and disclosure requirements like EUDR and TCFD typically focus more on **what** to measure than **how** to do so. As a result, there is still a need for collaboration across the EO industry to define shared standards fulfilling regional and global environmental commitments and frameworks. Non-profit organizations, industry consortiums and intergovernmental bodies can all play a role in positioning EO to capitalize on these driving forces for growth.

CASE STUDY 2

Apple combines satellite and in-situ sources to track carbon removal progress

Issue

As part of its commitment to carbon neutrality across its entire value chain by 2030, Apple launched the EO-enabled Restore Fund. This key initiative supports projects to restore and protect critical ecosystems and expand carbon removal solutions, helping to address residual emissions businesses cannot yet avoid. As the projects so far cover 250,000 acres of land, measuring and quantifying the impact on carbon removal would be challenging with traditional, on-the-ground measurement methods.[49]

Solution

With $400 million in funding to date, Apple addressed this issue using EO data, including high-resolution satellite imagery from Maxar, to develop carbon maps of the projects. Additionally, Apple is looking to use iPhone light detection and ranging (LiDAR) sensors as a source of in-situ data to bolster existing satellite data. This allows Apple to accurately monitor each project, as well as quantify and verify the carbon removal. Accurate quantification and measurement of the carbon removal impact of Restore Fund projects will help Apple better track and report its progress towards carbon neutrality in 2030.[50]

Impact

By implementing cutting-edge technology, Apple not only enhances its ability to track and showcase the effectiveness of its carbon removal initiatives but also increases transparency in its data-driven strategy to address climate change.

3.2 Vulnerability analysis

Virtually any organization that manages or has an interest in physical assets can find applications for EO to support vulnerability analysis. The broad applicability of EO for vulnerability analysis is rooted in the diversity of hazards across natural and human-made systems that can be observed.

Changing environmental conditions pose wide-ranging hazards to built infrastructure, human health, biodiversity and more. By providing insights into these hazards, EO data helps organizations make data-driven decisions and take a proactive rather than reactive mitigation approach. For example, the ability to monitor areas where vegetation is encroaching on power lines helps utility companies perform preventive maintenance that reduces the likelihood of fires starting. In turn, this helps avoid both ecosystem and financial losses.

In a preparedness context, modelling the size and distribution of human populations can enable organizations to develop data-driven strategies to mitigate disaster risk and improve response plans. For example, public health agencies can infuse EO data into models about where and when diseases may spread to help mitigate severity. The EO4Health Initiative developed a dengue fever forecasting system using EO data to map high-risk areas and create an early warning system.[51]

From a financial viewpoint, this typically translates to preventing or reducing losses, including through protecting natural systems that businesses from tourism to agriculture depend on. After all, over half the world's total GDP is moderately or highly dependent on nature.[52] EO-enabled vulnerability analysis also facilitates market activities based on risk assessments in industries ranging from government to insurance and financial services. For example, monitoring the changing sea levels or the effects of beach erosion helps assess risks to coastal properties, thereby informing insurance coverage and premiums.

CASE STUDY THREE

Tokio Marine and ICEYE partner to use EO for disaster insurance

Issue

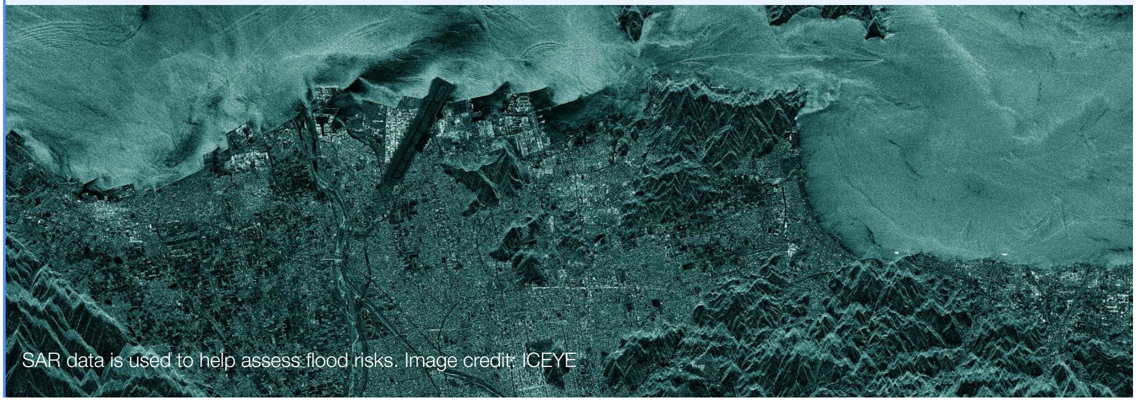
Insurance providers assess disasters from two sides: estimating the risk of an event (potential frequency and magnitude) and claims after an event.[53] With the increasing frequency of disasters, private insurance company Tokio Marine sought a technology that would pre-emptively assess risk to set more accurate premiums and make insurance payments as quickly as possible.

Solution

Tokio Marine partnered with ICEYE Finland to implement ICEYE's synthetic-aperture radar (SAR) imaging capabilities, which provide near-real-time analysis to assess the extent of damage from events such as flooding, allowing them to calculate losses and process claims more quickly.[54] Tokio Marine and ICEYE look to further their collaboration efforts, using EO to inform on the climate risk of a building and set premiums more accurately at the onset while better informing occupants of the risk.

Impact

An improved understanding of existing and future climate risks generates significant operational value for Tokio Marine by guarding against climate-driven premium losses and giving Tokio Marine a competitive advantage in claim response time. This approach also has impacts beyond the organization itself. By more accurately factoring climate risks into insurance pricing, Tokio Marine and other insurers can exert market pressure on developers to account for climate considerations in their construction projects so that insurance premiums remain at commercially viable rates.



SAR data is used to help assess flood risks. Image credit: ICEYE

> EO-enabled vulnerability analysis facilitates market activities based on risk assessments in industries ranging from government to insurance and financial services.

3.3 Supply chain monitoring

Applications to track and optimize supply chain operations include supervising the movement of goods, assessing transport routes and ensuring ethical sourcing by providing visibility into upstream commodity suppliers.

Organizations can deepen insight into weather conditions, traffic patterns, infrastructure conditions and hazards that impact the supply chain, identifying disruptions either in real time or through predictive analytics. Additionally, companies can use EO data to enhance their supply chain efficiency and monitoring by optimizing delivery routes to decrease travel time and transport costs and increase accuracy.

EO data also enables organizations to trace the origins of products and raw materials to promote accountability for illegal activities and unethical practices in companies' supply chains. These insights enable organizations to assess the sustainability of resource use and reduce unsustainable activities, such as deforestation, throughout their value chains.

CASE STUDY FOUR

Nestlé uses satellite data to advance responsible sourcing of palm oil

Issue

Palm oil appears in about half of the products found at supermarkets today and is in high demand as a common ingredient due to its cost-competitiveness and versatility. Production tripled between 2000 and 2020, leading to significant deforestation and habitat loss from clearing land to cultivate oil palms.[55] Nestlé has been working for more than 10 years on reducing the risk of deforestation in its palm oil supply chain, using a combination of tools to map, monitor and inform interventions.

Solution

In 2017, Nestlé began working with Starling – a collaborative venture between Airbus and the Earthworm Foundation – to incorporate satellite data into its supply chain mapping and deforestation monitoring efforts. With optical and radar data from Starling, Nestlé monitors over 9,000 farms. When deforestation is linked to its suppliers, Nestlé works with them to develop and implement collaborative remediation strategies.[56] Satellites support ongoing monitoring of the palm supply chain and, more recently, are being piloted to add transparency to the company's reforestation projects.

Impact

Using Starling data has helped Nestlé identify, understand and address the drivers for deforestation in its supply chain. The company reports that as of 2023, 96% of its palm oil supply chain was assessed as deforestation-free,[57] up from 70% in 2020.[58] Further, through its reforestation efforts, the company aims to plant and grow 200 million trees in its sourcing landscapes by 2030.[59]

> “ EO data also enables organizations to trace the origins of products and raw materials to promote accountability for illegal activities and unethical practices in companies' supply chains.

4

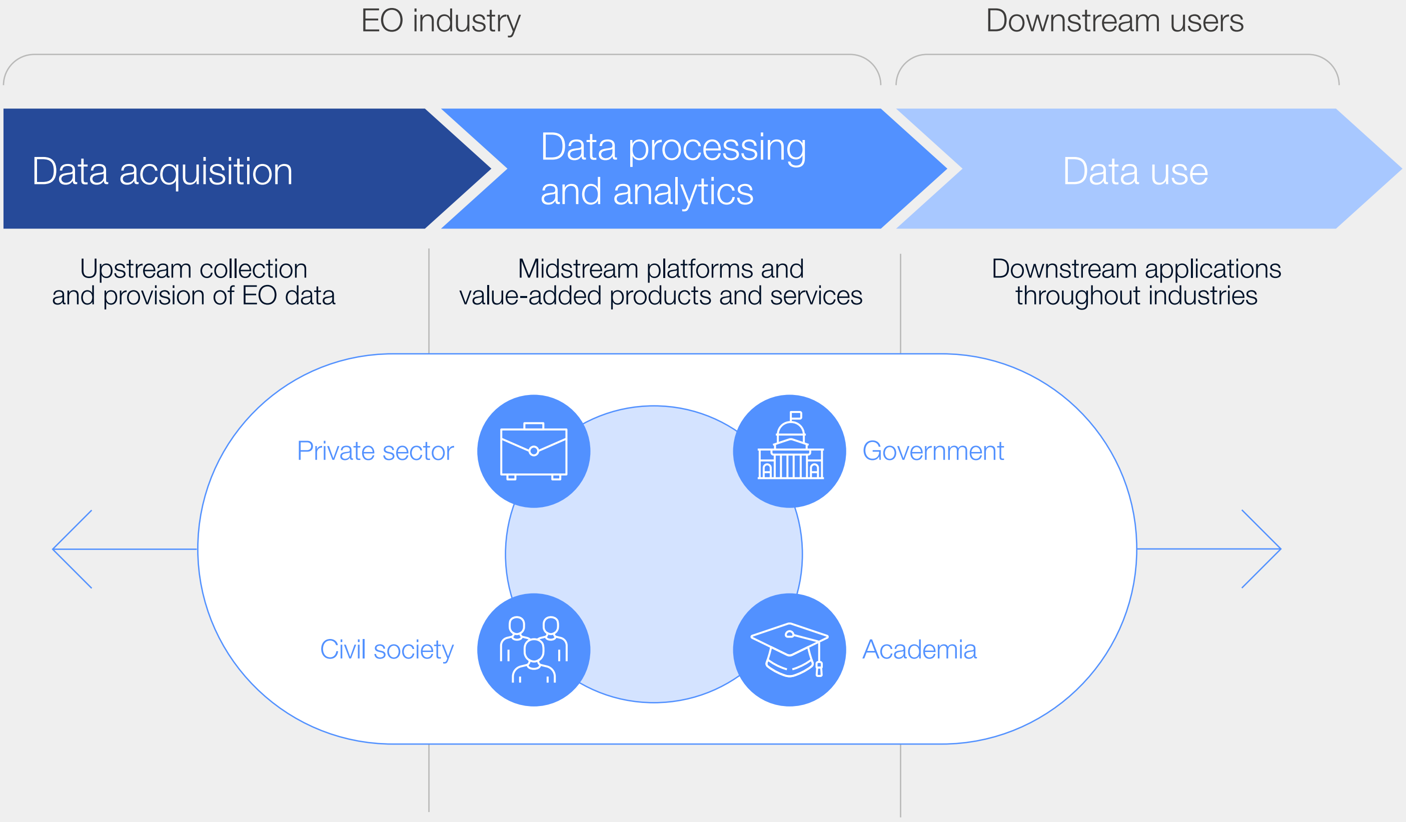
Strategies to activate EO's potential

Maximizing the global impact of EO calls for collaborative action across the value chain.

EO is an extraordinary tool for creating both economic value and positive environmental impact. Maximizing that value and impact depends on a dramatic increase in global adoption. The following sections offer strategies to advance EO uptake and the value derived from it.

To succeed in these strategies, one underlying theme is clear: **sustained multi-disciplinary collaboration is essential**. With near-endless applications for EO, each with its own unique technical requirements, industry dynamics, geographic and cultural nuances, user preferences, dependencies, and implementation models, a one-size-fits-all approach simply does not work. Instead, collective action is needed from a vibrant ecosystem that spans the entire value chain, as shown in Figure 17.

FIGURE 17 **The EO ecosystem**



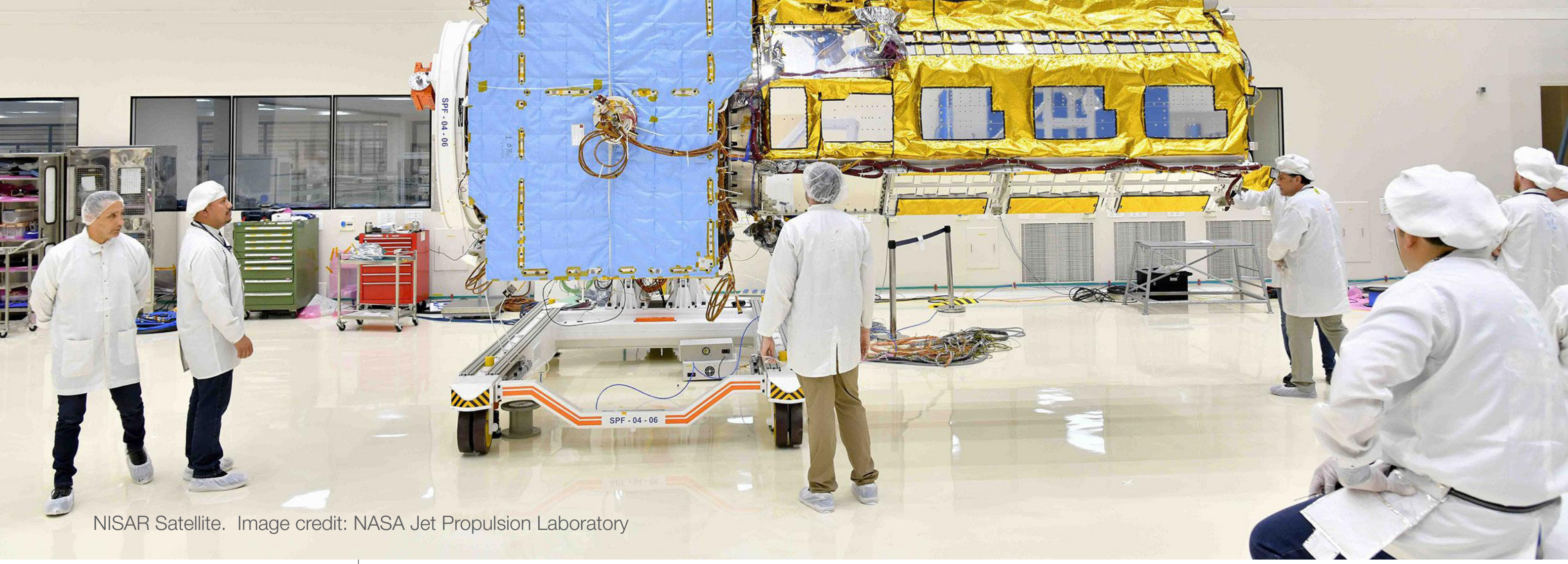
1. Open the aperture of end-user awareness

The tide is shifting among many global executives, but awareness of EO is still limited. A lack of awareness of industry-specific and function-specific applications remains a barrier to adoption. Addressing this barrier is largely a matter of educating end users, but it is not just the role of commercial EO providers.

Governments play an important part in building awareness and can do so by continuing to share success stories from public investments, setting policy and advocating for EO's use in applications that benefit society and the economy. Academia and civil society organizations can play a similar role and bring an independent, objective voice to complement and balance the marketing efforts of commercial EO providers. Acknowledging the gaps and limitations of EO solutions can go a long way in building trust and avoiding unrealistic expectations from end users. Academic and research institutions can also contribute by helping to build the knowledge base around EO data. A focus on advancing critical thinking using Earth data, beyond the simple use of geospatial software, will ensure that students can develop more flexible and adaptable skills to address a wide variety of challenges using EO.

Finally, industry leaders looking to find advantages by using EO can start by investing in building an EO-ready workforce. This includes having team members who are aware of the capabilities of EO measurements and the relevant applications within their industry, as well as encouraging the use of

> **“ Acknowledging the gaps and limitations of EO solutions can go a long way in building trust and avoiding unrealistic expectations from end users.**



NISAR Satellite. Image credit: NASA Jet Propulsion Laboratory

Over the past decade, new satellites and sensors have dramatically expanded the quality, coverage and range of EO data available.

geospatial problem-solving. Resources from public sector EO programmes, such as NASA's Applied Remote Sensing Training (ARSET) programme, provide a valuable resource for training.

2. Enable innovation with open standards, data and solutions

Continued innovation in services and business models is key to expanding the reach of EO to new end users, and access to EO data is a prerequisite for researchers and start-ups to explore new possibilities. However, expensive datasets that are hard to access can hold back the experimentation that's needed in early-stage research and development. Open standards, data and solutions can help bridge the gap. According to Jed Sundwall, Executive Director of Radiant Earth, "Open data that uses widely adopted standards can support the creation of many more applications that can reach esoteric audiences of end users".

Standards like the SpatioTemporal Asset Catalog (STAC) and Analysis Ready Data (ARD) aim to ensure interoperability and maximize the value of geospatial data. They are industry-driven, with input from the open-source community in coordination with groups such as the Cloud-Native Geospatial Foundation and the Committee on Earth Observation Satellites (CEOS). Despite significant uptake from major industry players, more work is needed across the EO ecosystem to establish consistent definitions, build consensus and increase the adoption of standards.

Open data and solutions are also key ingredients for a robust ecosystem of value-added services since they allow for low-risk experimentation and innovation among start-ups.[60] Cloud platforms like Amazon Open Data, Google Earth Engine and others make EO data and analytics tools publicly available, supporting research, technology development as well as ultimately expanding the impact and applications of these critical datasets. Providing free access to limited commercial datasets, as Umbra has done with SAR data, is another promising approach to support exploration.

3. Continue investment to advance EO technologies

Over the past decade, new satellites and sensors have dramatically expanded the quality, coverage and range of EO data available. At the same time, advances in high-performance computing, cloud, edge processing and AI are helping unlock the rich insights buried in the vast quantity of EO data. Pushing the boundaries of these technologies is important to fuel innovative downstream applications, and investment from both the public and private sectors plays an important role.

The private sector has driven a rapid cycle of remote sensing technology innovation, fuelled by internal research and development (R&D) investments and external capital raises. For example, venture capital firm DCVC, which focuses on technology start-ups addressing challenges in the space and climate industries, provided early investment to Planet Labs, helping to establish the daily global imaging capability they are known for. Matt O'Connell, Operating Partner at DCVC, said, "Venture capital is willing to lean forward enough to build out the capabilities that are necessary".

In the public sector, national programmes and international collaborations also play an important role in fielding next-generation EO capabilities. For example, NASA and the Indian Space Research Organization (ISRO) partnered to develop the NASA-ISRO Synthetic Aperture Radar (NISAR) satellite, which will use a first-of-its-kind technique designed to provide wide coverage and fine-resolution radar observations at the same time.[61] Costing $1.5 billion and requiring a decade to develop, NISAR is a typical example of a major innovation made possible with government backing. Government funding is also an important stimulus for innovation in the private sector and academia, such as the UK Space Agency's investments in early R&D of EO technology through the Earth Observation Technology Program.[62]

Non-profit and philanthropic organizations like Digital Earth Africa play a crucial role by translating available EO data into services that target unique community-level challenges.

4. Focus on equity in access to EO insights

Based on modelled adoption rates, markets in the Global South – particularly in Africa – stand to realize the greatest percentage growth in the value of EO from 2023 to 2030. Accelerating uptake can have a real impact on economic growth and help tackle issues from water scarcity to food security.

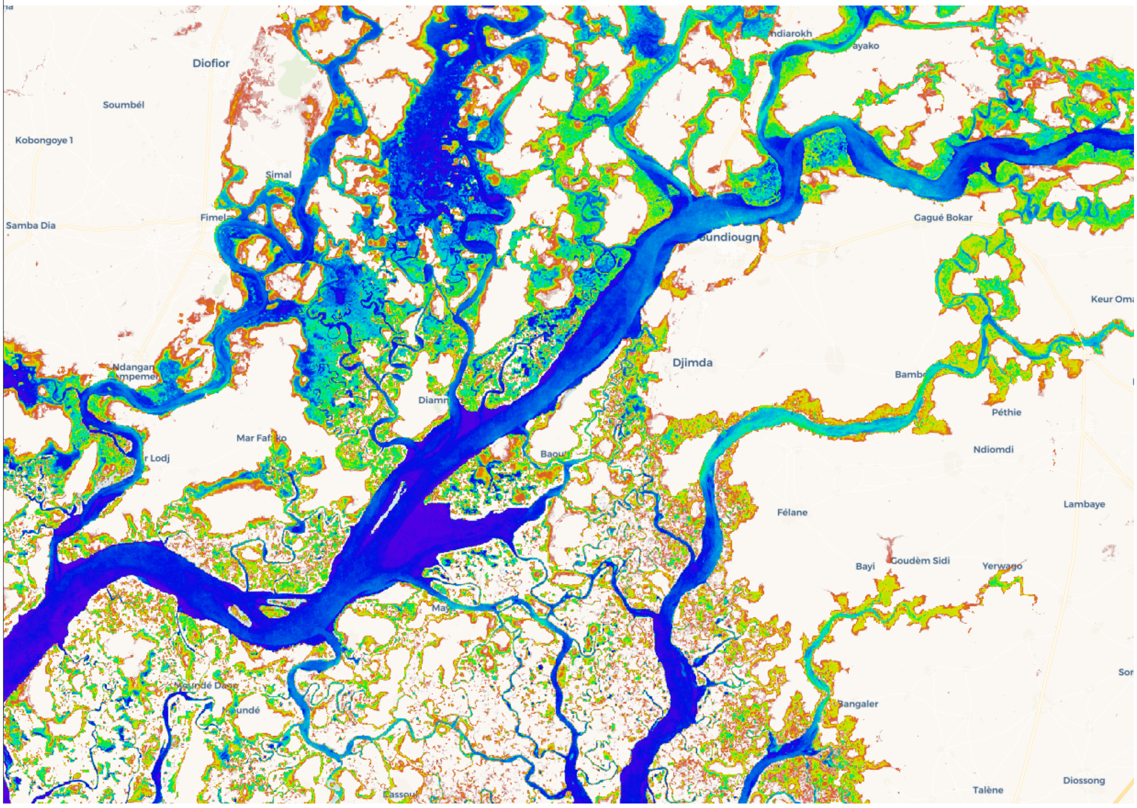
Government agencies play a foundational role upstream, whereby programmes provide free access to thousands of datasets. Yet, broadening the utility of these datasets for end users can require shifting from data to insights and establishing cloud-native standards like STAC to facilitate use. In the US, the Inflation Reduction Act (IRA) provided the National Oceanic and Atmospheric Association (NOAA) with over $3 billion to help the country build climate resilience. A significant portion of that funding is dedicated to improving services derived from Earth data for underserved communities.[63]

Non-profit and philanthropic organizations like Digital Earth Africa play a crucial role by translating available EO data into useful information and services targeted to the unique challenges faced by different communities.[64]

5. Provide solutions, not pixels, to reach new customers

Beyond technology improvements, business model innovation is critical to getting EO insights in the right hands. According to Euroconsult, 37% of the $5.5 billion in cumulative funding raised in the EO industry between 2011 and 2022 flowed to value-added services.[65] When compared to the 150-fold value increase enabled midstream and downstream in the EO value chain, that proportion seems imbalanced. Additional focus from investors and EO providers on creating value-added services tailored to downstream applications is likely needed to extract the full value of new SAR, hyperspectral, LiDAR and other sensors that are coming online.

Investment doesn't have be limited to the EO industry alone. For example, a mining company founded in 2018, KoBold Metals, has now raised more than $400 million to capitalize on opportunities in AI- and geospatial-driven solutions to find deposits of copper, lithium and other minerals needed to support the energy transition.[66] Luca Budello, Geospatial Lead for Innovate UK Business Connect, said, "If we don't integrate EO-based outputs into the systems that end users actually use, it doesn't create the actionable intelligence they need to make decisions". Consultancies and other intermediaries can help amplify the reach and uptake of EO data by translating capabilities into solutions that are tailored to their clients' unique challenges. In doing so, these intermediary players can lower barriers to adoption.



Processed image of a river in Senegal showing the prevalence of water from 2013 to 2019 in false colour (blue = always water, green = sometimes water, red = never water). Image credit: DE Africa

Conclusion

Earth observation's ability to inform valuable decisions across nearly all industries lends to a compelling value proposition. The technology's outlook is encouraging but not without challenges. Barriers, including limited awareness of EO applications, a shortage of specialized talent, fragmented standards and difficulty navigating the complex EO marketplace, are limiting uptake. Even applications that have demonstrated their feasibility in project-based environments need investment to mature into scalable solutions.

However, there is optimism among EO industry professionals about the role that enabling technologies like AI can play in making EO accessible to non-experts and lowering the demand-side barriers to entry. Exciting developments in satellite and sensor technology, advanced computing and a growing ecosystem of Earth intelligence providers are also pushing the envelope of what is possible with EO data.

As the Chief Impact Officer of Planet Labs, Andrew Zolli, commented, "The library science era of EO is about to end".

Between 2023 and 2030, Earth observation could add a cumulative $3.8 trillion to the global economy while eliminating more than 2 Gt of GHG emissions per year. These outcomes present a compelling case for greater adoption and collaborative action from every player on the value chain is needed to make this future state of EO a reality. Prioritizing the implementation of dual-value EO applications is not only key to unlocking economic value and growing the EO industry, but it is also a vital strategy to advance climate- and nature-focused goals by 2030. Through a collective focus on stimulating demand, advancing the use of AI and other enabling technologies and establishing key standards needed to make Earth data ubiquitous, Earth observation can help shape a more sustainable and prosperous future for generations to come.

Appendices

A1 Methodology and approach

This study estimated the potential economic value generated not only by the Earth observation (EO) sector but also from the use of EO data across downstream industries. Economy-wide spillovers from the use of EO were not quantified but captured qualitatively.

The growth path was modelled based on an increase in the adoption of EO technology at the global level out to 2030. As noted by Sobhanmanesh et al, "the approach to technological transformation varies depending on location, industry, and organisation".[67] Key modelling parameters include:

- **Scale and attribution of benefit across industries**: In what ways, and by how much, do different industries benefit from the use of EO?
- **Current and future adoption**: What is the current adoption rate possible across the economy? How will this change in the future?
- **Technology adoption profiles across industries**: By how much does the propensity to adopt technology vary by industry?
- **Accounting for regionality**: How will the adoption of EO technology be impacted by structural economic differences across regions?

To capture these key aspects, this report's technology adoption model, used to estimate the economic and climate impact of EO on the global economy, was built following these steps:

Step 1: Estimate the current value of the EO sector

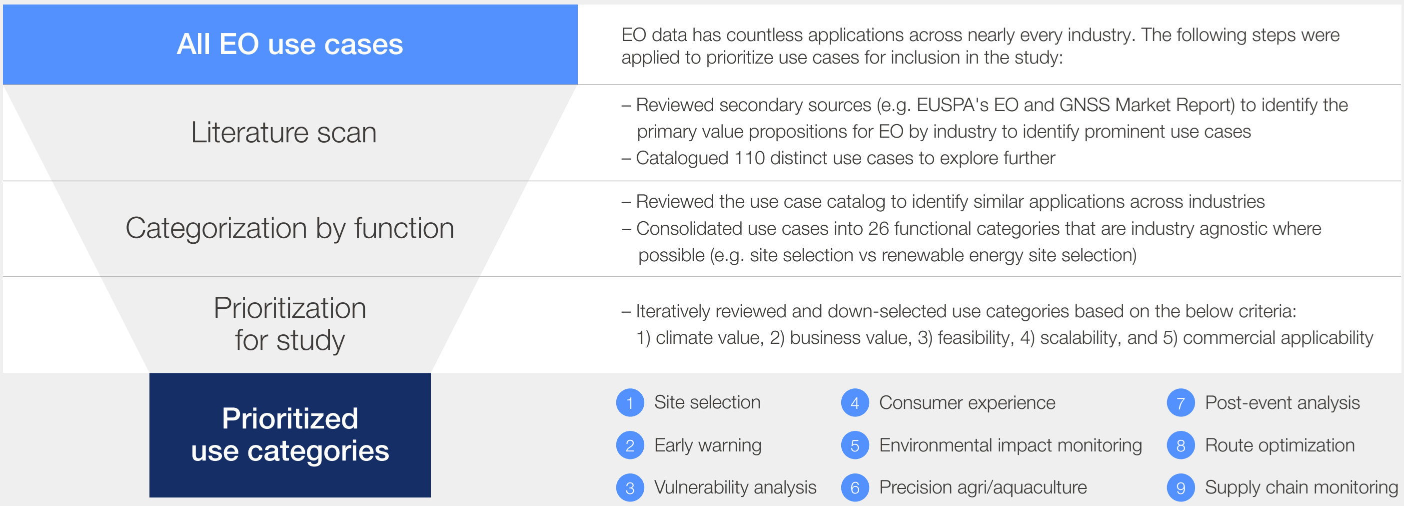
The European Union Agency for the Space Programme's (EUSPA)[68] *EO and GNSS Market Report* was used to inform the current value of the EO industry. EUSPA valued the EO industry through revenue estimates of data and value-added services sales. Notably, this valuation is limited to commercial transactions and excludes most government and defence activities.

Revenue figures were transformed into value-added figures using the value added-to-revenue ratio of the information, media and technology (IMT) sector, provided by the Global Trade Analysis Project (GTAP) database.[69] The IMT sector was chosen as a proxy for EO data and services providers as it encompasses the EO industry.

Step 2: Estimate the current value of benefits derived by EO users

To estimate the value added by EO use to the global economy, a "bottom-up" approach was taken to capture the marginal benefit of use across a range of sectoral applications. To inform this process, a catalogue of use cases was established, which was then narrowed into broader categories (see Figure 18). The criteria for prioritization in this study reflected the importance of having representative uses that reflect the breadth of EO capability, geographic spread, applicability and examples of uptake across a broad range of sectors.

FIGURE 18 **Use case selection**



EO data has countless applications across nearly every industry. The following steps were applied to prioritize use cases for inclusion in the study:

– Reviewed secondary sources (e.g. EUSPA's EO and GNSS Market Report) to identify the primary value propositions for EO by industry to identify prominent use cases
– Catalogued 110 distinct use cases to explore further

– Reviewed the use case catalog to identify similar applications across industries
– Consolidated use cases into 26 functional categories that are industry agnostic where possible (e.g. site selection vs renewable energy site selection)

– Iteratively reviewed and down-selected use categories based on the below criteria: 1) climate value, 2) business value, 3) feasibility, 4) scalability, and 5) commercial applicability

1 Site selection
2 Early warning
3 Vulnerability analysis
4 Consumer experience
5 Environmental impact monitoring
6 Precision agri/aquaculture
7 Post-event analysis
8 Route optimization
9 Supply chain monitoring

Next, a literature review captured evidence of **economic benefit directly attributable to applications of EO across industries**. The following selection criteria were used:

- **Evidence of use**: Evidence was found demonstrating current use in industry (pilot applications excluded).
- **Quantified benefits**: Marginal benefit to the user has been documented and verified (anecdotal evidence excluded).
- **Attribution**: Marginal benefit must be directly attributable to EO.

The literature review established a series of industry-use pairs (i.e. examples of a specific use of EO in an industry). For each pair, research was undertaken to characterize the nature of the benefits, current and potential future users and primary beneficiaries. This process resulted in an understanding of the mechanisms by which value created by EO is transmitted through the economy and the identification of **global marginal benefit parameters**, which represent the incremental value added to the industry that can be attributed to the use of EO (typically a percentage, such as the percentage of additional output or reduction in losses). Table 11 lists the parameters used to model the value of EO in this study.

TABLE 11 **Marginal benefit parameters for modelled applications of EO**

Use category	#	Industry (user)	Application	Description of parameter due to EO	Derived parameter
Precision agriculture	1	Agriculture (crops)	Precision agriculture for cropping	Additional crop output[70,71]	Cotton: 5.3%* Corn: 4.5%* Wheat: 7.5%* Soybeans: 0.9%* Other: 4.8%*
	2	Agriculture (livestock)	Grazing decisions and pasture management	Additional livestock output[72]	Cattle: 13%* Pigs: 8%* Dairy: 13%* Chickens: 8%*
	3	Agriculture (forestry)	Precision forestry, harvest optimization	Forestry productivity increase[73,74,75]	20%*
	4	Agriculture (fisheries)	Water quality (aquaculture, wild capture)	Reduced damage from harmful algal blooms[76]	30.6%
Supply chain monitoring	5	Government	Efficient regulation	Reduction in foregone tax and environmental damage from reduction in illegal activity[77,78]	Gold mining: 10% Logging: 20%
	6	Financial services	Responsible supply chain tools	Contribution to tools' market value-added[79]	50%
	7	Supply chain	Proof of origin and sustainable sourcing	Price premium for verified proof of origin[80,81,82,83,84]	Palm oil: $30 per tonne Cocoa: $70 per tonne Cotton: 12.5% Sugar cane: 13% Lithium: 30% Cobalt: 30% Rare earths: 30%
	8	Financial services	Market efficiency	Increased return on assets under management[85,86]	5.24%*
Early warning	9	Global capital stock (cross-industry)	Wildfire detection	Avoided losses to capital stock due to early detection[87,88]	16%
	10	Agriculture	Wildfire detection	Avoided losses in agriculture[89,90]	16%
	11	Global capital stock (cross-industry)	Flood extent mapping	Avoided losses to capital stock[91]	$2,266 per hectare*
	12	Global capital stock (cross-industry)	Landslide detection	Reduced losses from landslide mitigation[92,93]	13.2%

Use category	#	Industry (user)	Application	Description of parameter due to EO	Derived parameter
Site selection	13	Mining	Resource exploration	Efficiency from added exploration accuracy[94,95]	7.9%*
	14	Electricity	Optimal location selection for clean energy assets	Marginal benefit to clean energy investment planning[96]	33%
	15	Professional services, construction	Urban planning	Productivity gain of global construction industry[97]	0.03%
Post-event analysis	16	Health	Earthquake response management	Reduction in mortality (value of a statistical life)[98]	20%
	17	Government, emergency services	Earthquake response management	Reduced response costs during a disaster[99]	12%
	18	Government, emergency services	Volcano eruption response management	Reduced costs to affected industries[100]	12%
	19	Insurance	Flood event mapping (post event)	Efficiency gains to insurers during a disaster[101]	90%
Vulnerability analysis	20	Government, public services	Improved information for road planning, surveying and maintenance	Cost savings as a proportion of investment and maintenance spend[102,103]	0.10%*
	21	Utilities	Gas and water pipeline monitoring	Efficiency gains from improved gas and water pipeline monitoring[104]	$619 per kilometre of pipeline*
	22	Agriculture	Value of weather forecasts	Value-added per hectare of seasonal weather forecasts.[105,106]	Livestock: $2.9 per hectare Crops: $30.4 per hectare
	23	Financial services	Value of weather forecasts	Additional output from improved productivity[107,108]	0.08%*
	24	Mining			0.14%*
	25	Manufacturing			0.08%*
	26	Transport			0.04%*
	27	Information and media			0.05%*
	28	Utilities			0.07%*
	29	Construction			0.05%*
	30	Supply chain			0.02%*
	31	Tourism			0.03%*
	32	Insurance			0.08%*
	33	Professional services			0.08%*
	34	Health			0.12%*
Consumer experience	35	Health	Air quality alert apps	Reduced morbidity[109]	0.01%
Route optimization	36	Transport	Shipping	Fuel saved[110]	2.98%
	37	Transport	Urban traffic congestion	Reduced congestion costs[111]	1.6%

*Adjusted from the original source to include industry weighting, regionalization of the parameter or a combination of sources to capture the most robust benefit parameter suitable for this modelling exercise.

The **maximum potential annual value of EO** was determined by applying the marginal benefit parameter to the **global size of the relevant industry**, generally using gross value add (GVA). A stylized overview of this process is shown in Figure 19.

Each region's potential value was also split out using its relative GVA.

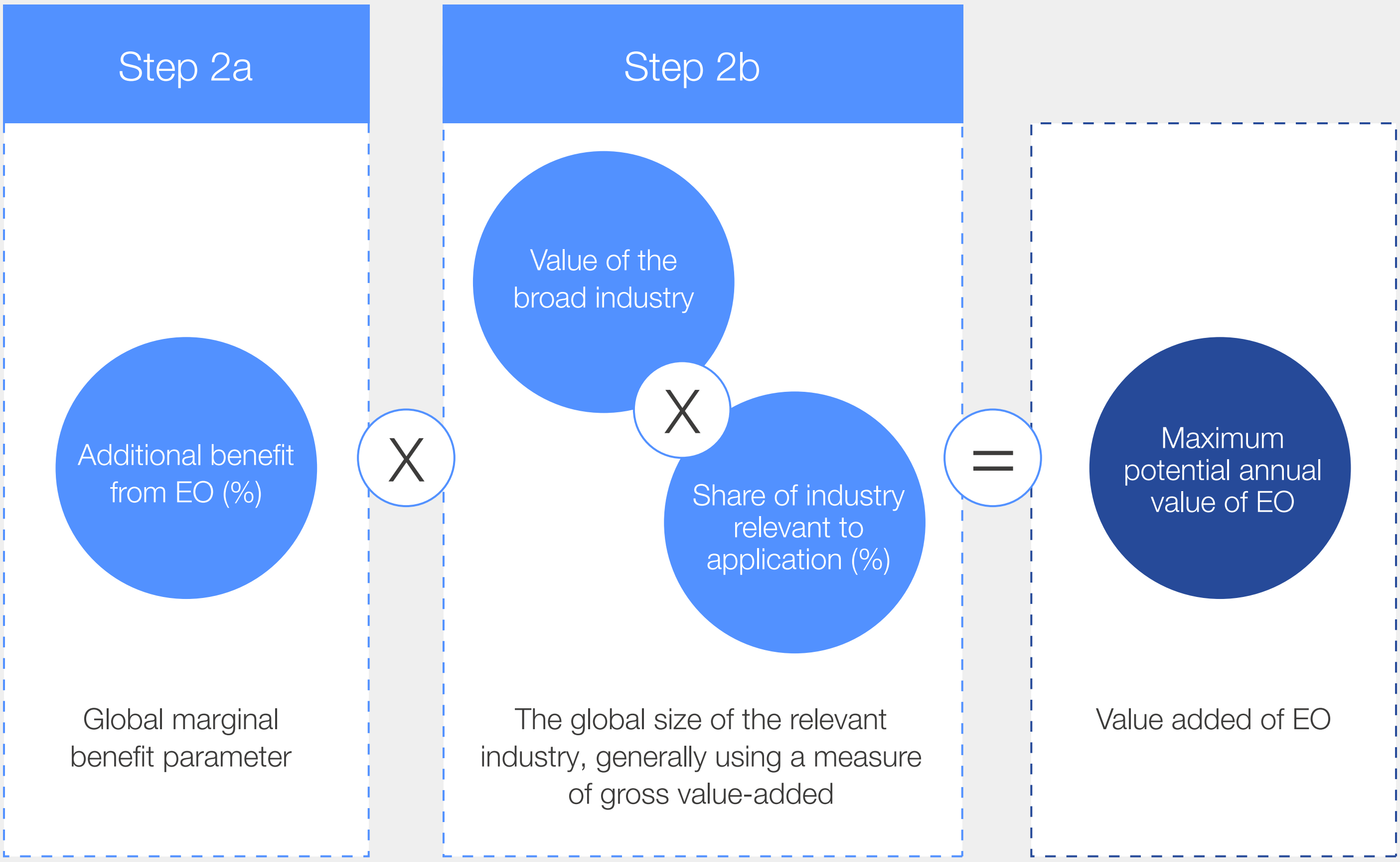
The result of this equation is the **maximum** potential annual value of EO. It represents the value of an EO application if an entire industry were to adopt it. To estimate the **actual** potential value of EO, the maximum potential value was scaled to account for adoption dynamics within industries, as explained in step 3 below.

Step 3: Parameterize and model

To project adoption rates, the Bass Model, a specialized tool for assessing technology diffusion, was employed with custom parameters to capture heterogeneity in EO adoption between industries and regions. The Bass Model was identified as best suited to project adoption of EO as it is supported by empirical evidence and can be adapted in a variety of circumstances using available data and, as such, is used widely for modelling technology adoption.[112]

Adoption reflects the share of industry using EO, measured by GVA. This is a non-standard assumption for Bass model analysis, which typically uses the number of people or businesses using a technology to represent adoption. This assumption was required due to an absence of global data on the number of businesses in each industry. Box 6 shows a stylized version of the model output.

FIGURE 19 **How the economic value of EO applications is estimated**

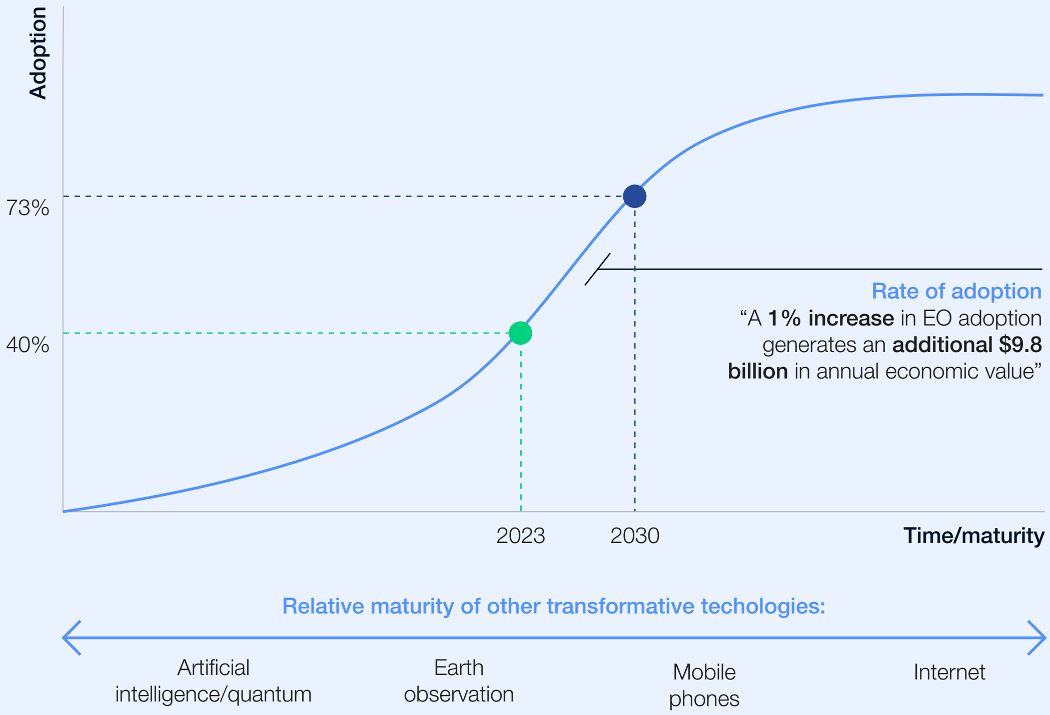


BOX 6

Linking the adoption model and the valuation

The adoption model generates a curve that traces out a percentage of adoption over time. This adoption curve is then multiplied against the total potential value that could be realised by using EO in each sector, giving a **total potential use value of EO over time**.

To account for differences in economic growth by industry and region, each region's industry shares were drawn from GTAP and regional-level economic growth forecasts were taken from the International Monetary Fund (IMF). IMF economic growth forecasts account for expected inflation by region.



Rate of adoption
"A **1% increase** in EO adoption generates an **additional $9.8 billion** in annual economic value"

A global survey of industry experts (most respondents indicated they had at least more than 10 years of experience with EO) was conducted to parameterize the technology adoption model. This survey captured information about the current EO adoption rate by sector and use category, expectations for adoption over time by industry, use category and region. Key questions related to the adoption model are outlined in Table 12.

In total, 51 survey responses were received from the following industry groups:

- EO industry: n=21 responses
- Commercial EO users: n=16 responses
- Others (academia, government and thought leaders): n=14 responses

TABLE 12

EO valuation – survey questions to inform adoption model

#	Survey question	Use in valuation
1	For the industry you selected, please indicate the extent to which you think the industry uses EO data at the global level today	Used to inform an industry specific rate of adoption of EO
2	For the industry you selected, please identify what proportion of the industry you believe will never use EO as part of their operations in the future	Used to define the adoption ceiling for EO, which reflects the potential market saturation of EO in each industry
3	Please reflect on your industry in general. Use the sliding scale below to rate technology adoption in your industry	Used to develop an industry index of technology adoption to capture differences between sectors as they relate to EO technology

Prior to incorporation into the adoption model, survey responses at the sectoral level were tested and refined through discussions with six specialists in the EO industry located in both the US and Australia. The validation process considered the preliminary adoption rates generated by the survey for each industry.

Based on the review, adoption rates were adjusted to reflect an overall adoption pathway for global industries that were both internally consistent and aligned to academic literature and other work addressing technological adoption and readiness. The resulting estimates of potential adoption rates are shown in Table 13.

TABLE 13

Modelled rates of EO adoption by industry in 2023 and 2030

Industry	2023	2030
Agriculture	37%	71%
Construction	25%	58%
Financial services	39%	79%
Government	50%	80%
Health	30%	53%
Information, media and technology	34%	59%
Insurance	28%	88%
Manufacturing	35%	66%
Mining	60%	81%
Professional services	27%	72%
Tourism	30%	53%
Supply chain	40%	71%
Transport and infrastructure	40%	72%
Electricity and utilities	41%	72%

Step 4: Estimation of greenhouse gas (GHG) emissions reduction

Quantification of potential GHG emissions reductions attributable to EO followed an approach similar to the economic valuation.

Based on a literature review, applications with the potential to inform actions that directly prevent or reduce GHG emissions were identified. Marginal benefit parameters were defined for each application (see Table 14).

TABLE 14

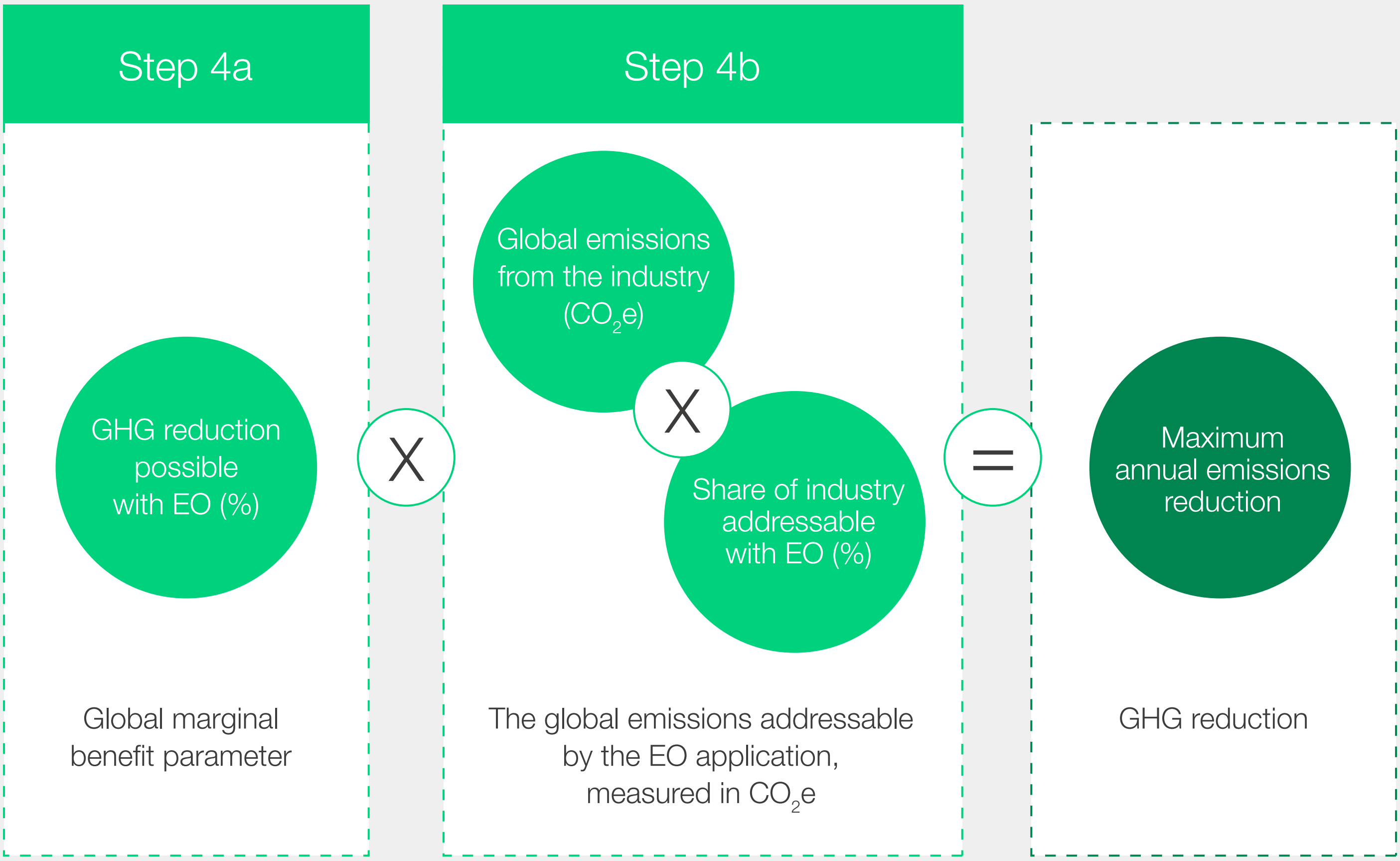
Marginal benefit parameters for GHG reduction

Use category	Application	Marginal benefit parameter due to EO
Early warning	Forest fire detection	Reduction in burnt area (16%)[113]
Environmental impact monitoring	Emissions monitoring	Preventable methane emissions from oil and gas industry (70%)[114]
Precision agriculture/ aquaculture	Variable rate application of input treatments	Reduction in fertilizer use (5%)[115]
Supply chain monitoring	Illegal deforestation monitoring	Preventable deforestation (10%)[116, 117]
Route optimization	Ship navigation with dynamic route planning	Reduced fuel consumption (3%)[118]

The marginal benefits were used to extrapolate possible GHG reduction to global levels using regional and industry parameters (see Figure 20).

Finally, the maximum annual emissions reductions were adjusted downward based on modelled adoption rates for the applicable EO use category following the same Bass curve established for the economic valuation.

FIGURE 20 **How the GHG reduction from EO applications is derived**



A2 Taxonomy of EO uses and applications

The following list of applications, organized by use category, was established as a baseline to guide primary and secondary research throughout this study (as explained in step 2 of the methodology). Applications in this list are mapped to corresponding economic modelling as shown below and fall within one of three categories.

1. **Applications explicitly modelled** met the criteria for inclusion described in step 2 of the methodology. These are denoted with the corresponding number(s) from Table 11.
2. Applications **indirectly captured** by modelling include those that did not meet the criteria for inclusion but have indirect benefits that support or enable the applications explicitly modelled.
3. Applications that were **not captured** in modelling but demonstrate emerging or non-monetary benefits.

TABLE 15 List of EO applications by use category and inclusion in economic modelling

Use category	Application	Alignment to economic modelling (Table 11)
Consumer experience	Air quality monitoring	35
	Games and gamification of in-situ data collection	Not captured
	Geo-advertising	Not captured
	Geo-tagging	Not captured
	Mapping and navigation	37
	Sports, fitness and wellness	37
	Ultraviolet (UV) radiation monitoring	Indirectly captured
Early warning	Early warning for disasters	9, 10, 12
	Earthquake and tsunami monitoring	16, 17
	Floods monitoring	11
	Forest fire detection	9, 10
	Landslides and terrain deformation monitoring	12
	Locust swarm monitoring	Not captured
	Storm surge monitoring	Indirectly captured
	Vector-borne disease forecasting	Indirectly captured
	Volcanic activity monitoring	18
	Weather forecasting	1, 4, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 36, 37
Environmental impact monitoring	Agricultural policy monitoring and enforcement	7
	Air quality monitoring in urban environments	35
	Aircraft emission impact assessment	Not captured
	Biomass monitoring	Indirectly captured
	Carbon sequestration capacity assessment	Not captured
	Climate forecasting	1, 4, 8, 9, 10, 14, 15, 17, 21, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34
	Climate mitigation and adaptation strategies	Indirectly captured
	Climate modelling	Indirectly captured
	Deforestation/degradation monitoring	7
	Ecosystem monitoring	Indirectly captured
	Emissions monitoring	Indirectly captured
	Energy and materials extraction impact monitoring	7
	Environmental auditing	Indirectly captured
	Environmental impact assessment for infrastructure	Indirectly captured
	Environmental impact assessment to inform environmental, social and governance (ESG) policies	7
	Environmental resources management	Indirectly captured

Use category	Application	Alignment to economic modelling (Table 11)
Environmental impact monitoring	ESG indicator monitoring and reporting	Indirectly captured
	Forestry management certification	7
	Light pollution monitoring	Indirectly captured
	Marine pollution monitoring	Not captured
	Thermal auditing	Indirectly captured
	Urban greening	Indirectly captured
	Urban heat islands	Indirectly captured
Post-event analysis	Development assistance monitoring	Not captured
	Event footprint analysis	19
	Infrastructure and supply chain restoration	17
	Population displacement monitoring	Not captured
	Post-disaster damage assessment and building inspection	19
	Refugee settlement management	Not captured
	Search and rescue operations support	16
Precision agriculture/ aquaculture	Aquaculture operations optimization	Indirectly captured
	Climate forecasting for agricultural planning	Indirectly captured
	Crop yield forecasting	1
	Drought monitoring	Indirectly captured
	Farm management systems	Indirectly captured
	Field definition	Indirectly captured
	Fish stock detection	4
	Fishery harvest optimization	4
	Forest inventory monitoring	3
	Forest vegetation health monitoring	Indirectly captured
	Pastureland management	2
	Precision irrigation	1
	Soil condition monitoring	1
	Variable rate application of input treatments	1
	Vegetation monitoring	1
Route optimization	Autonomous surface vessel navigation	Not captured
	Drone operations planning	Not captured
	Hazardous weather identification	30
	In-land waterways navigation	Not captured
	Marine surveying and mapping	36
	Maritime autonomous surface ships operations	Not captured
	Maritime traffic monitoring	Indirectly captured

Use category	Application	Alignment to economic modelling (Table 11)
Route optimization	Particulate matter monitoring	Not captured
	Post-processing for airspace management	Not captured
	Road navigation	37
	Road traffic monitoring	37
	Sea ice navigation	36
	Ship route navigation	36
	Terrain obstacles monitoring for aviation	Not captured
Site selection	Aquaculture site selection	Indirectly captured
	Dredging operations intelligence	Not captured
	Infrastructure site selection and planning	20
	Mineral exploration and site planning	13
	Renewable energy operations monitoring	14
	Renewable energy plant design optimization	14
	Renewable energy productivity forecasting	14
	Urban development planning	Indirectly captured
	Urban mapping and land use classification	15
	Urban modelling and digital twins	15
Supply chain monitoring	Commodities trading intelligence	8
	Dark vessel monitoring	Not captured
	Illegal logging monitoring	Indirectly captured
	Illegal mining monitoring	5
	Illegal, unreported and unregulated fishing control	Not captured
	Port security	Not captured
	Supply chain insights	6
Vulnerability analysis	Aircraft maintenance and operation optimization	Not captured
	Construction monitoring	20
	Construction permitting	Not captured
	Disaster preparedness	9, 10, 11, 12
	Energy network conditions monitoring	28
	Environmental hazards monitoring	9, 10, 12
	Infrastructure monitoring	12, 20, 21
	Investment risk exposure analysis	23
	Land subsidence monitoring	Indirectly captured
	Natural hazards monitoring	Indirectly captured
	Parametric insurance	Not captured
	Pipeline monitoring	21

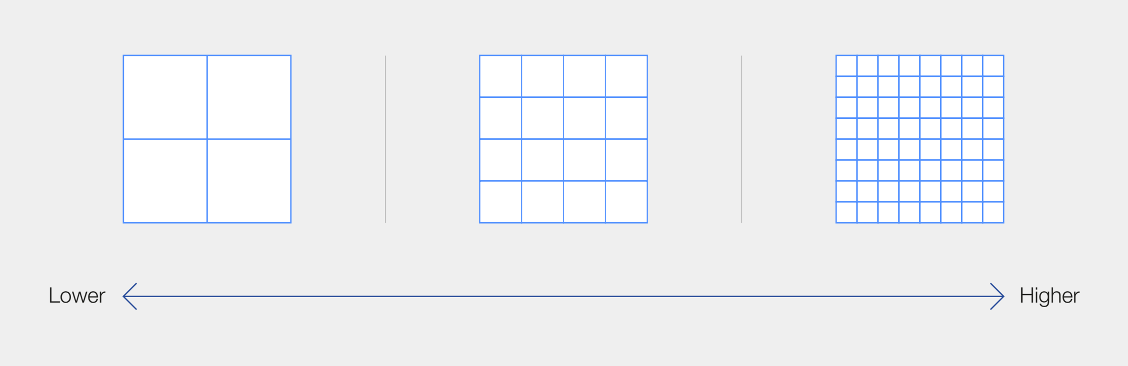
Use category	Application	Alignment to economic modelling (Table 11)
Vulnerability analysis	Port operations safety	Not captured
	Post-construction monitoring	20
	Property valuation	Not captured
	Risk assessment for energy production and raw materials extraction	24
	Risk modelling for insurance premium calculation	8

A3 EO data types and their uses

The effectiveness of EO is shaped by a set of key attributes. Each of these defines what type of data is collected and how, and each plays a vital role in ensuring the quality and utility of the collected data.

FIGURE 21

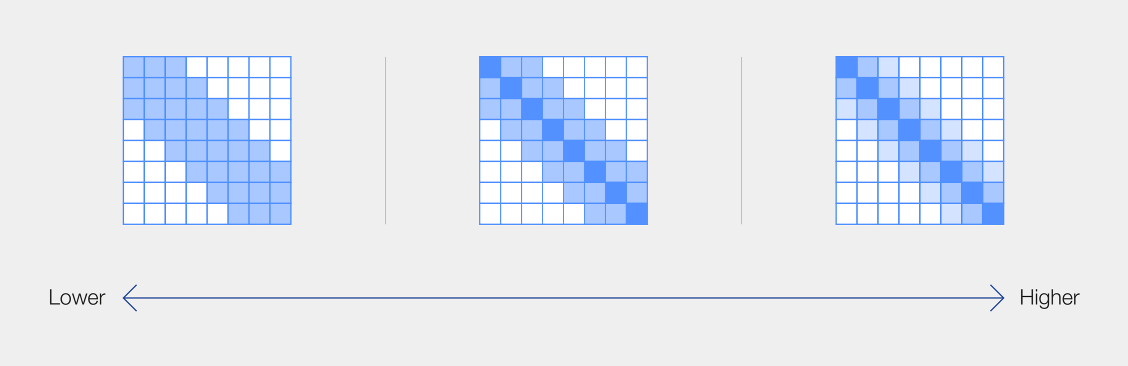
Spatial resolution



Spatial resolution (measured in metres per pixel) allows for information extraction from images. It enables the analysis and observation of Earth's surface and is characterized by a trade-off between detail and coverage; higher resolution provides finer details but covers less area, while lower resolution is better for broader land classification and land use analysis.

FIGURE 22

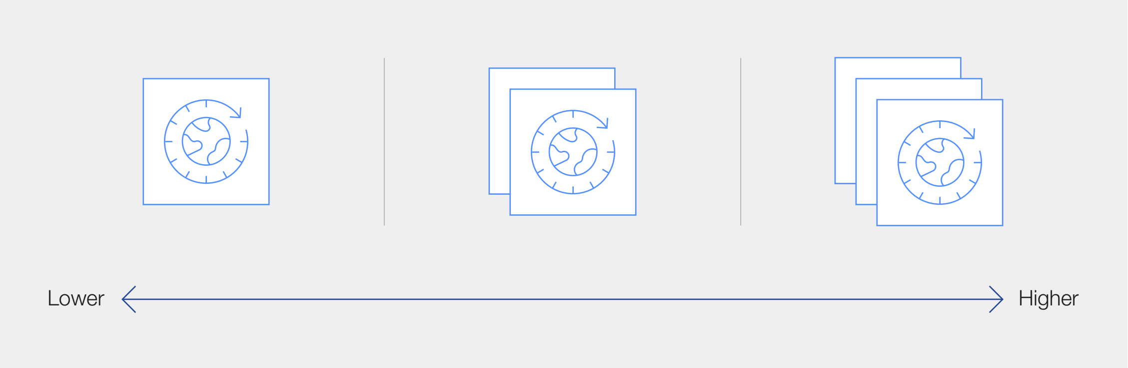
Radiometric resolution



Radiometric resolution (sensitivity) is defined by NASA as "the amount of information in each pixel, that is, the number of bits representing the energy recorded".[119] Higher radiometric resolution means an instrument can detect smaller differences in electromagnetic energy, producing more bits per pixel.

FIGURE 23

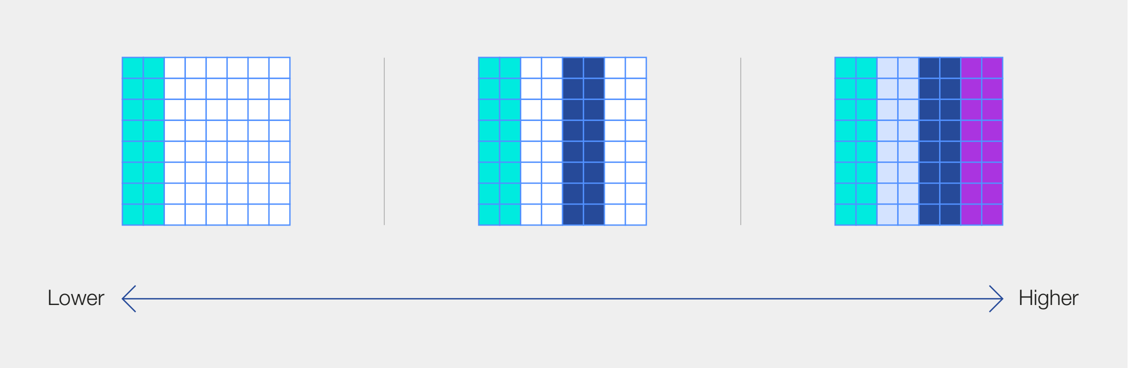
Temporal resolution



Temporal resolution refers to the time it takes for a satellite to revisit the same observation area. A high temporal resolution or revisit rate is associated with frequent revisits and is useful for monitoring quickly changing conditions.

FIGURE 24

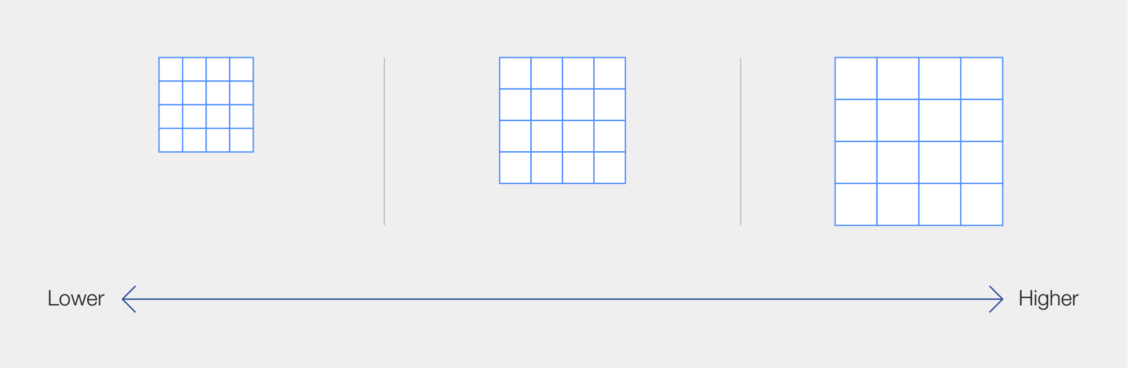
Spectral resolution



Spectral resolution refers to electromagnetic energy's variations in wavelength and frequency across a spectrum. Finer spectral resolution allows sensors to differentiate narrower ranges on that spectrum. Some specialized instruments, called multispectral or hyperspectral sensors, can observe many distinct wavelengths at once.

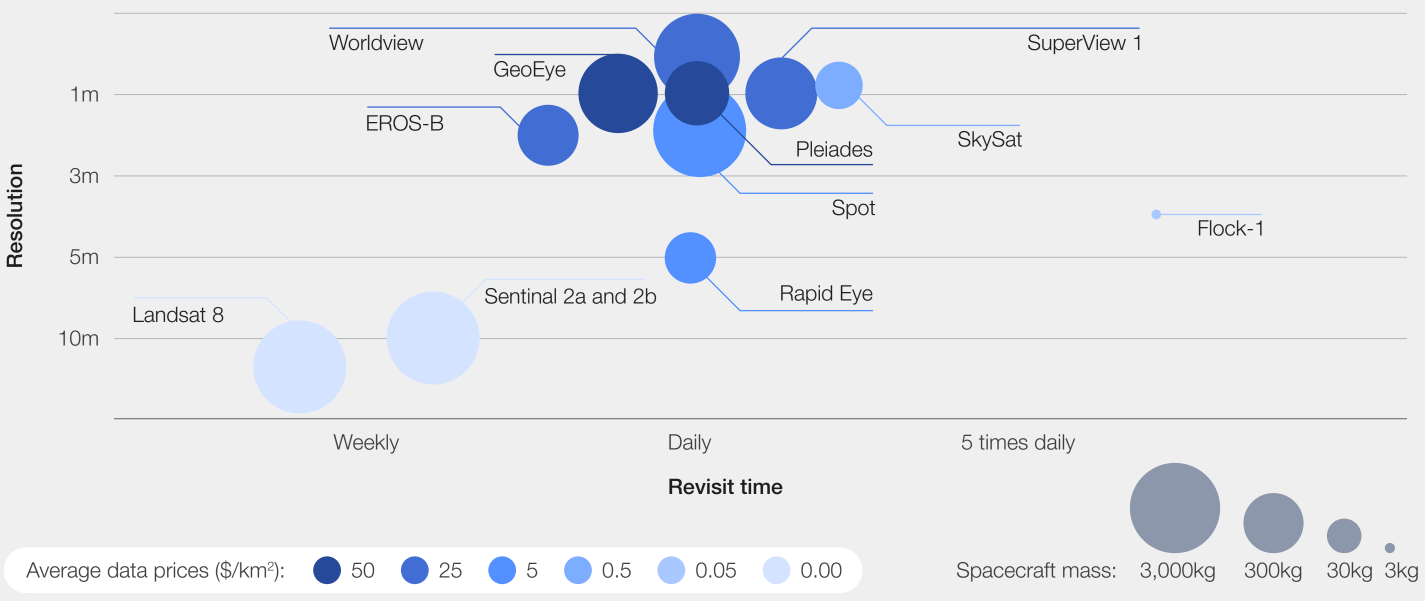
FIGURE 25

Scene size



Scene size refers to the extent or area of the Earth's surface that is being imaged in each frame. There is typically a trade-off between scene size and spatial resolution whereby higher spatial resolution images are captured in narrower scenes and vice versa.

FIGURE 26 Spatial resolution vs revisit time for various satellites



Source: Satellite Applications Catapult 2017, adapted from: Enright, K. (2023). A definitive guide to buying and using satellite imagery. UP42. https://up42.com/blog/a-definitive-guide-to-buying-and-using-satellite-imagery.

TABLE 16 Select types and applications of remote sensing EO data

Data type	Definition	What can be measured	Common applications
Visible spectrum imaging	Captures reflected light in the visible spectrum (colours)	Sun's energy reflected on the Earth (only measurable during the day)	Environmental monitoring, object mapping, forestry
Infrared spectrum imaging	Captures thermal radiation (infrared light)	Temperature and heat distribution	Thermal mapping, GHG emissions detection, anthropogenic heat sources and vegetation health monitoring
Microwave spectrum imaging	Captures radiation in the microwave spectrum	Surface roughness and moisture content	Weather forecasting, soil moisture measurement
Multispectral imaging	Captures reflected energy in the visible and infrared spectrum; typically 3-10 wider bands	Generalized spectral signatures, helping to identify some chemicals/ compounds	Agriculture, land cover classification
Hyperspectral imaging	Captures reflected energy in the visible and infrared spectrum; typically over 100 narrow bands	Highly detailed spectral signatures, providing greater differentiation between chemicals/ compounds	Mineral identification, environmental monitoring; tree species classification
Synthetic aperture radar (SAR) (active sensor)	Transmits and receives electromagnetic waves in the radio spectrum	Distance to objects and surface roughness	Terrain mapping, terrain analysis and disaster monitoring
Light detection and ranging (LiDAR) (active sensor)	Emits laser pulses and measures return time	3D topography, object heights	Terrain mapping, terrain analysis, forestry, hydrology

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