WGEO

WORLD GREEN ECONOMY ORGANIZATION

World Green Economy Report

Satellite Applications to Accelerate the Green Economy

Caribou Space

World Green Economy Organization

https://worldgreeneconomy.org/

The World Green Economy Organization (WGEO) is a comprehensive response to calls by the international community for a holistic approach to spur progress on how and why a green economy is the world's best route towards a safe and prosperous future.

The path from the Rio+20 United Nations Conference on Sustainable Development in 2012 to the passage of the new 2030 Agenda for Sustainable Development and the Paris Agreement has seen strong levels of commitment by world leaders to shift to a green economy.

WGEO seeks to promote the widespread acceptance and increased importance of a green economy in the context of sustainable development and poverty eradication.

WGEO intends to support emerging global actions towards the green, low-carbon, climate resilient development model. The organization is framed to operationalize green economy concepts on the ground through results and impact-oriented action.

WGEO is headquartered in Dubai, United Arab Emirates.

Caribou Space

www.caribou.space

Caribou Space supports organisations to bridge the space and sustainable development worlds by working with governments, space agencies, development agencies, and private sector space companies. Caribou Space provides:

- Official Development Assistance (ODA) fund and programme strategy: Strategic recommendations for the design and delivery of ODA programmes.
- Fund management: For large-scale ODA funds (£100M+) and seed-stage funds (£4M+).
- Monitoring and Evaluation (M&E): Design of M&E systems, delivery of process and impact evaluations, and M&E training.
- Research, communications, and knowledge sharing: Conducting research on market opportunities, user needs, use cases, and impact of space solutions. Sharing knowledge publicly of what works and doesn't work—and why—through diverse communications channels including press and media, publications, social media, conferences, and workshops.
- Programme management: Delivery of complex, multi-country, multi-million-pound programmes in lower-income countries.
- Product strategy: Supporting strategy for the sustainability and commercialisation of space solutions for lower-income countries.
- Economic evaluation: Quantification of the economic case and impacts of space solutions.

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Foreword

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As we explore innovative technologies to attain global transition into a green economy, satellite applications are expected to play a crucial role in delivering on sustainable development commitments.

HE Saeed Mohammed Al Tayer
Chairman, World Green Economy Organization

The World Green Economy Organization (WGEO) advocates for and supports enhancing innovative technologies to fulfil its commitment to a global green economy transition. We believe key pillars of this transition are the exchange of knowledge, experience, and best practices, and the use of innovative technology. The Satellite Applications to Accelerate the Green Economy Report is yet another example of our commitment to be a catalyst of change for this transition. We are grateful to our partners for sharing their successes with us and allowing us to compile an exhaustive and robust picture of the clear framework for the deployment of satellite applications, highlighting the importance of enhancing technology to attain a sustainable green economy.

Through this report, we seek to inspire leaders and organisations across the Middle East and North Africa (MENA) region to identify measures that can be taken to address key issues and capitalise on the significant opportunity these technologies present.

The report reiterates the importance of continued innovation in developing applications that meet the needs of local communities, government agencies, and civil society organisations in a cost-effective and impactful manner. The report underpins that the greater uptake of satellite technologies will depend on the actions of the sector’s supply and demand chains. The report summarises future action areas for initiators to pilot in the MENA region and globally according to specific barriers identified in the region. It further examines 28 use cases for satellite applications for the green economy in five domains, including ten in the urban sector, three in the transport sector, four in the waste sector, seven in energy, extractives, and industry, and four in tourism.

The report also examines 19 case studies from around the globe, including the MENA region, to underscore a range of different satellite applications and their benefits. One such case study is Dubai Electricity & Water Authority’s (DEWA) space programme (Space-D) initiative, aimed at improving the operations, maintenance, and planning of its networks with the support of nanosatellite technology, Internet of Things (IoT), and remote sensing technologies. In January 2022, DEWA launched the DEWA-SAT 1 nanosatellite, becoming the world’s first utility to use nanosatellites to improve the maintenance and planning of electricity and water networks.

We need to embark on a new journey for humanity, one which continues to pursue green development by accelerating the transition in our growth model and enhancing our economic structure by harnessing innovation, including the use of satellite applications to accelerate the green economy.

Foreword

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Earth observation, satellite communications, and navigation systems, are being applied to society's green economy challenges across the urban, transport, waste, tourism, and energy, extractive & industry sectors.

David Taverner
Senior Director, Caribou Space

Governments, the private sector, and NGOs, require access to high quality information to make informed decisions to address green economy issues, but in many countries, there is a lack of data or it is incomplete, out-of-date, or expensive to collect. Conversely, satellite applications can offer these decision makers data that is quick to access, affordable, repeatable, and covers the globe.

Multiple factors have converged, and the time has come for satellite applications to be adopted as a mainstream tool for addressing green economy issues. Public good satellite constellations such as Europe's Copernicus and the US's GPS provide free and open access data. Computing costs have continued to fall and parallel advances in cloud platforms, data science and machine learning have reduced the costs and complexity to access and process satellite data.

The advantages of speed, affordability and coverage that are offered by satellite technologies mean that they are often the best - if not the only - way of addressing these green economy issues. This represents a huge opportunity for the satellite services industry to develop applications that can be adopted by governments, policy makers, investors and private enterprise all over the world.

Caribou Space has collaborated with World Green Economy Organization (WGEO) to publish this report to accelerate the use of satellite applications for the green economy.

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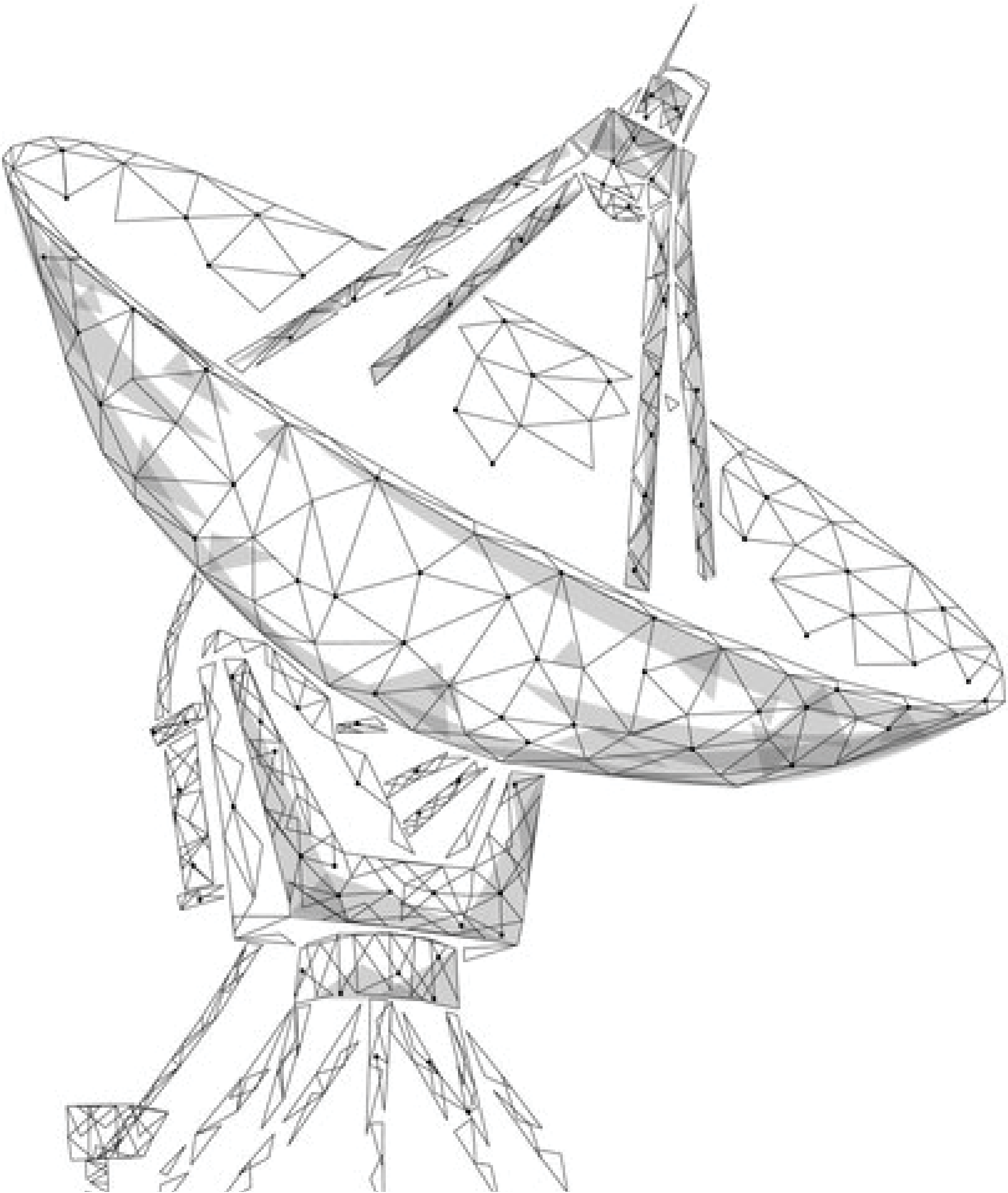


Executive Summary

Satellite Applications to Accelerate the Green Economy

This report was commissioned by the World Green Economy Organization to advance the use of satellite applications within the green economy. It aims to clarify the landscape of satellite applications for the green economy, to catalyse stakeholder collaboration, and to identify and evaluate opportunity areas for future interventions.

The United Nations Environment Programme (UNEP) defines the green economy as *"low carbon, resource efficient and socially inclusive."* UNEP also defines two sub-aspects of the green economy, with respective domains/sectors:

- *Investing in natural capital* – interlinked with nature, natural resources, and ecosystem services.
- *Investing in energy and resource efficiency* – focused on reducing energy and resource consumption/use.

This report focuses on domains aligned with "investing in energy and resource efficiency," including urban, transport, waste, energy, extractives and industry, and tourism. The use of satellite applications in the domains of "investing in natural capital" is already well documented, including in agriculture, fisheries, and forests, including by Caribou Space in the report *Adoption and Impact of Earth Observation for the 2030 Agenda for Sustainable Development*.[1]

Satellite applications are digital services and products that serve several functions for society, the environment, and the economy, by deploying three types of satellite technology: Satellite Earth Observation, Satellite Communications, and Global Navigation Satellite Systems. Organisations from across the private and public sector are involved in the supply of satellite applications. These range from satellite owners and operators, to cloud companies, software providers, and analytics and solution providers.

In parallel there is a diverse community of users of satellite applications for the green economy, including government, private sector, development agencies, media, academia, and NGOs. In MENA countries there are many governmental entities, such as ministries, authorities, and public companies, that are potential users of satellite applications for a green economy. This report identifies 28 use cases for satellite applications across the domains of urban (10), transport (3), waste (4), energy, extractives and industry (8), and tourism (4). Nineteen case studies are provided from the MENA region and beyond to highlight a wide range of different satellite applications and their benefits.

However, there are a number of barriers to the further adoption of satellite applications for the green economy. Some of these barriers relate to the supply of satellite applications (i.e., supply-side barriers), including: access to financial and non-financial resources to develop applications, availability of data and human talent, regulatory constraints, and excessive piloting and duplication of applications, largely funded through 'project' based financing.

There are also barriers to greater uptake of satellite applications among the user community (i.e., demand-side barriers), including: a lack of user awareness, resistance (particularly from government ministries/agencies), limited evidence of impact, lack of technical expertise and skills for usage, IT infrastructure, procurement challenges, and the level of green economy aspirations. This report explores these barriers and provides brief examples for them.

Finally, this report outlines some recommendations for specific interventions that could be planned to address the barriers outlined above. These interventions could involve—and benefit—key stakeholder groups such as climate change organisations, the private sector, government bodies, and academia. The recommended activities to generate the maximum potential in MENA address four issues:

- Raising awareness of use cases for satellite technology
- Building technical expertise and capacity
- Developing new satellite applications
- Demonstrating the viability of satellite applications with key user groups

In conclusion, satellite applications will have an important role to play in informing 'green' decision-making and investment. However, interventions are needed within both the supply chain and demand chain of the industry to accelerate the uptake and impact of these technologies within the green economy.

1 Caribou Space, Adoption and Impact of Earth Observation for the 2030 Agenda for Sustainable Development, May 2020, www.caribou.space/wp-content/uploads/2020/07/Caribou-Space_ESA-EO-for-Agenda-2030-v2-1.pdf

Report Background

Key points

- UNEP defines a green economy as *"low carbon, resource efficient and socially inclusive."*
- UNEP also defines two sub-aspects of the green economy, with respective domains/sectors:
  - *Investing in natural capital* – interlinked with nature, natural resources, and ecosystem services.
  - *Investing in energy and resource efficiency* – focused on reducing energy and resource consumption/use.
- This report focuses on the domains aligned with *"investing in energy and resource efficiency,"* including urban, transport, waste, energy, extractives and industry, and tourism. The use of satellite applications in the domains of *"investing in natural capital"* is already well documented, including in agriculture, fisheries, and forests.
- Satellite applications are digital services and products that serve several functions for society, the environment, and the economy, by deploying three types of satellite technology: Satellite Earth Observation, Satellite Communications, and Global Navigation Satellite Systems.

Definition of the green economy

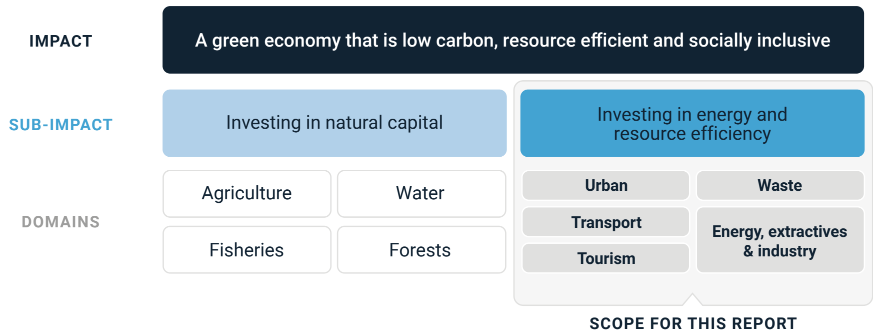
In October 2011, UNEP published a key report, *Towards a Green Economy: Pathways to Sustainable Development and Poverty Eradication*. It states that *"the concept of a 'green economy' does not replace sustainable development, but there is now a growing recognition that achieving sustainability rests almost entirely on getting the economy right."*[2]

Whilst there is no internationally agreed definition of green economy, and at least eight separate definitions have been identified, UNEP's definition is commonly used.[3] The UNEP defines a green economy as "low carbon, resource efficient and socially inclusive." This definition is used in this report.[4]

UNEP also defines two sub-aspects of the green economy, with respective domains/sectors:

1. **Investing in natural capital** – interlinked with nature, natural resources, and ecosystem services.
2. **Investing in energy and resource efficiency** – focused on reducing energy and resource consumption/use.[5]

Figure 1: Scope of this report



2 UN Environment Programme, Towards a Green Economy: Pathways to Sustainable Development and Poverty Eradication, 2011, www.greengrowthknowledge.org/sites/default/files/downloads/resource/Green_Economy_Report_UNEP.pdf

3 UN Department of Economic and Social Affairs Sustainable Development, 'Green Economy,' https://sustainabledevelopment.un.org/index.php?menu=1446

4 UNEP, Towards a Green Economy: Pathways to Sustainable Development and Poverty Eradication—A Synthesis for Policy Makers, 2011, https://sustainabledevelopment.un.org/content/documents/126GER_synthesis_en.pdf

5 Ibid.

Scope of this report

A domain, also known as a sector, is a broad grouping of different activities within the green economy. The focus of this report is on the domains aligned with *"investing in energy and resource efficiency,"* including urban, transport, waste, energy, extractives and industry, and tourism (Figure 1 and Figure 2).

The use of satellite applications in the domains of *"investing in natural capital"* is already well documented, including in agriculture,[6] fisheries,[7] and forests.[8] The water sector is also not included in scope, as the role of satellite applications in it has been documented extensively, including by Caribou Space in the report *Adoption and Impact of Earth Observation for the 2030 Agenda for Sustainable Development.*[9]

Urban: More than half the global population live in cities. More than 80% of global GDP is generated in cities, which also account for more than 70% of greenhouse gas emissions.[10] Well-planned, compact cities reduce transaction costs, make public spending on infrastructure and services economically viable, and facilitate generation and diffusion of knowledge. However, poorly planned urbanisation leads to environmental destruction, increased carbon emissions, transport congestion, poor air quality, and urban sprawl. As the dominant habitat for the world's population, the ways cities evolve matter greatly to the green economy.

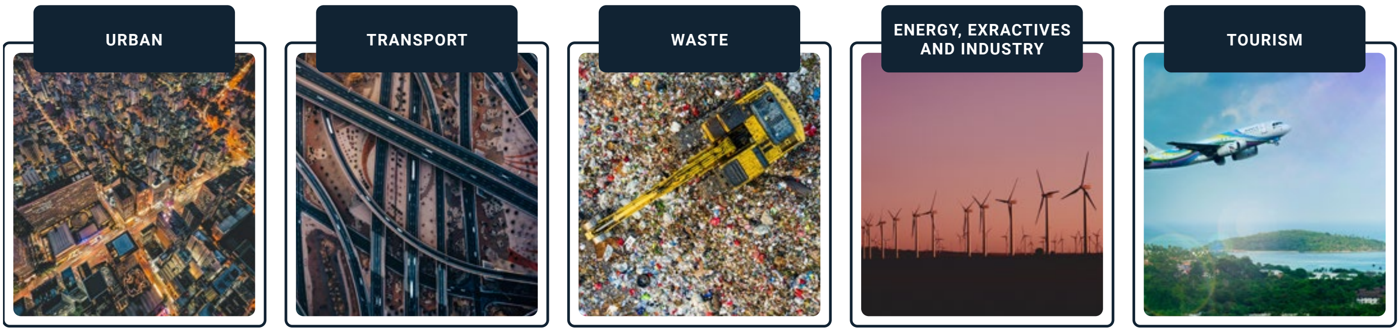
Transport: Sustainable transport has a key part to play in fostering inclusive growth, expanding access to essential services, and combating climate change. As transport contributes 23% of global energy-related greenhouse gas emissions, reducing the climate impact of transport is an urgent priority. Ambitious solutions are needed to lower the carbon footprint of existing and new transport systems.[11]

Waste: The world generates over two billion tonnes of municipal solid waste annually; at least 33% of which is not managed in an environmentally safe manner.[12] Poor waste management affects the quality of life of citizens of cities and rural areas, causes poor air quality through waste burning, leads to disease transmission, and contaminates rivers and oceans.[13]

Energy, extractives, and industry: Natural resources have the potential to drive growth, development, and poverty reduction, with the extractive industries sector playing a strong economic role in 63 countries.[14] However, these industries should aim to reduce carbon emissions and environmental risks, and protect local communities. The transition from fossil fuels to renewable energy sources is critical to decarbonise the global economy. Fossil fuel exploration and power generation and distribution must maximise efficiency to minimise greenhouse gas emissions.

Tourism: As a major component of the global economy, tourism contributes over 10% of both global jobs and global GDP.[15] However, it also leads to environmental pressures in tourist hot spots and increasing greenhouse gas emissions from transportation, especially air travel.

Figure 2: Green economy domains in scope



6 UK Space Agency, Space for Agriculture in Developing Countries, July 2018, www.spacefordevelopment.org/wp-content/uploads/2018/10/6.4502_UKSA_SPACEUK_Solutions-for-Agriculture_web.pdf; Caribou Space, Adoption and Impact of Earth Observation for the 2030 Agenda for Sustainable Development, May 2020, www.spacefordevelopment.org/wp-content/uploads/2020/07/Caribou-Space_ESA-EO-for-Agenda-2030-v2.pdf

7 Caribou Space, 'Space for Development: Maritime,' www.spacefordevelopment.org/topics/maritime/

8 UK Space Agency, Space for Forestry in Developing Countries, November 2018, www.spacefordevelopment.org/wp-content/uploads/2018/11/6.4918_UKSA_Forestry-Report_WEB.pdf; Caribou Space, 'Space for Development: Forestry and Land Use,' www.spacefordevelopment.org/topics/land-use/

9 Caribou Space, Adoption and Impact of Earth Observation for the 2030 Agenda for Sustainable Development, May 2020, www.caribou.space/wp-content/uploads/2020/07/Caribou-Space_ESA-EO-for-Agenda-2030-v2-1.pdf

10 The World Bank, 'Urban Development: Overview,' www.worldbank.org/en/topic/urbandevelopment/overview

11 The World Bank, 'Transport,' www.worldbank.org/en/topic/transport

12 The World Bank, 'What a Waste: Trends in Solid Waste Management,' https://datatopics.worldbank.org/what-a-waste/trends_in_solid_waste_management.html

13 Ibid.

14 The World Bank, 'Extractive Industries,' www.worldbank.org/en/topic/extractiveindustries/overview

15 World Travel and Tourism Council, 'Economic Impact Reports,' https://wttc.org/Research/Economic-Impact

Satellite Applications

Satellite applications are digital services and products that serve several functions for society, the environment, and the economy. They are beneficial today in a wide range of green economy use cases.

Due to the wide variety of use cases, satellite applications take many forms according to the needs and environment of stakeholders and the structure of solutions provided by suppliers. Satellite applications rely on a mix of technologies and expertise. Some are simple and widely available; others are advanced and specialist in nature. They incorporate three types of space-enabled technology:

Satellite Earth Observation (EO), also called satellite remote sensing, geospatial imagery, or satellite imagery, is the gathering of information about the physical, chemical, and biological systems of the planet via remote-sensing technologies. EO is used to monitor and assess the status of and changes in natural and built environments.

An important attribute of EO is "resolution": the smallest thing that can typically be seen (resolved) on the ground. The resolution grades are listed below:

- Very High Resolution (VHR) (<1m)
- High Resolution (HR) (1m–4m)
- Medium Resolution (MR) (5m–25m)
- Low Resolution (LR) (25m–60m)
- Very Low Resolution (VLR) (>60m)

VHR data is more expensive than data at lower resolutions, as it is sourced from Private Suppliers at commercial costs. Moreover, VHR data is also computationally more expensive. Lower resolution imagery (10m–200m) is available from Public Suppliers, such as the European Commission's Copernicus, at low or no cost.

Coverage is a broad term that describes the amount of EO data collected over an area or region with a given frequency. In general, Public Suppliers, such as Copernicus, have revisit times of five to eight days with global coverage. Private Suppliers offer higher revisit times for smaller areas as standard. For example, Planet provides new imagery up to twelve times daily from its SkySat constellation at 0.5m resolution.[16]

Satellite Communications (SatComms) is the use of satellites to provide communication links between various points on Earth. SatComms provide voice and internet connectivity in regions that are not covered by terrestrial mobile networks. Voice and data/internet services are now commonly available from both geostationary satellites, such as Eutelsat and Inmarsat, and numerous satellites in low Earth orbit (LEO) constellations, e.g., OneWeb[17] and Starlink.[18] Common SatComms-based services include telephony, mobile satellite services (MSS), and internet connectivity with all its associated digital services.

Global Navigation Satellite Systems (GNSS) are a constellation of satellites providing positioning, navigation, and timing (PNT) signals from space to GNSS receivers. GNSS is used to track people and physical objects at any time, globally. Many operational GNSS satellite constellations now exist and are operated by national governments.[19] These include GPS (USA), BeiDou (China), Galileo (EU), GLONASS (Russia), NavIC (India), and QZSS (Japan).

All three types of technology are advancing rapidly. The cost of building, launching, and operating satellites is decreasing, whilst the capabilities of the satellites are increasing.

For example, EO satellites that provide imagery of the whole planet, every day, with very high spatial resolution. In parallel, rapid advances in adjacent technology domains, such as cloud computing, data science, and machine learning, are also driving down costs and reducing the complexity of building satellite applications.

Finally, many of these technologies are global digital public goods. For example, the signals and data streams from the US GPS system and Europe's Copernicus EO system are available for free to everyone globally.

16 Martin Van Ryswyck, 'Planet Announces 50 Cm SkySat Imagery, Tasking Dashboard And Up To 12x Revisit,' Planet, 9 June, 2020, www.planet.com/pulse/tasking-dashboard-50cm-12x-revisit-announcement/

17 OneWeb, 'Network,' https://oneweb.net/network

18 SpaceX, 'Starlink,' www.starlink.com

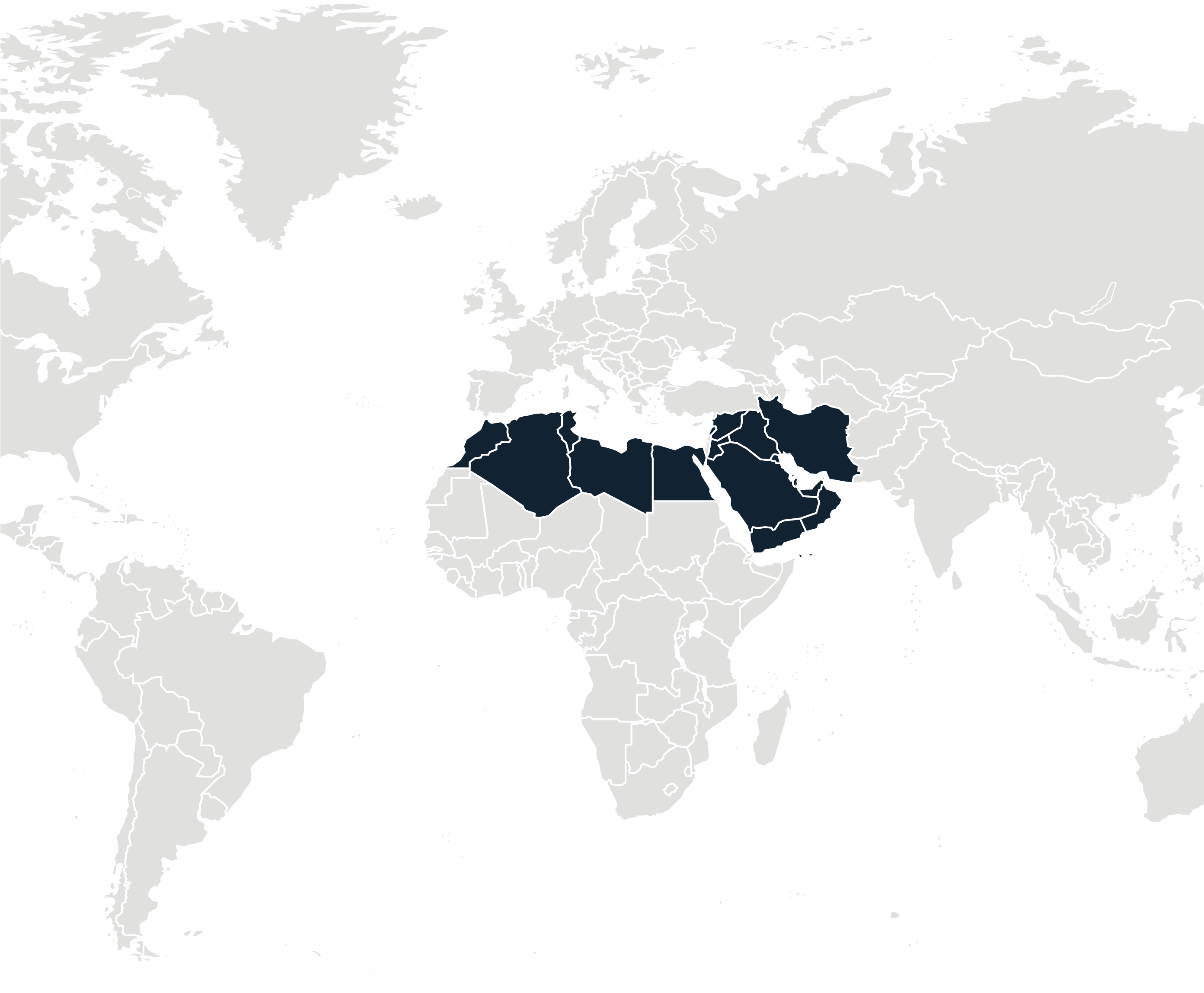
19 US National Coordination Office for Space-Based Positioning, Navigation, and Timing, 'Other Global Navigation Satellite Systems (GNSS),' www.gps.gov/systems/gnss/

The MENA Context

This report covers the use of satellite applications for the green economy from a global perspective, as WGEO has a global remit. It also provides a detailed view on Middle East North Africa (MENA). Many satellite applications programmes funded by European and US-based donor organisations to date have focused on projects in Latin America, Africa, and Southeast Asia. Comparatively less has been documented about satellite applications for the green economy in MENA—a gap this report with WGEO aims to close.

Whilst there is no standardised definition for MENA, for the purposes of this report, the World Bank definition is used which includes: Algeria, Bahrain, Djibouti, Egypt, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Libya, Malta, Morocco, Oman, Qatar, Saudi Arabia, Syria, Tunisia, United Arab Emirates, West Bank and Gaza, Yemen.[20] OECD states that *"Middle East and North Africa (MENA) is a diverse region, affected by economic and political transformations, but with a potential for more and better growth. It benefits from a privileged geographic location with access to large markets; a young and increasingly educated population; and comparative advantages in several sectors such as manufacturing, renewable energies and tourism."*[21]

Figure 3: MENA region



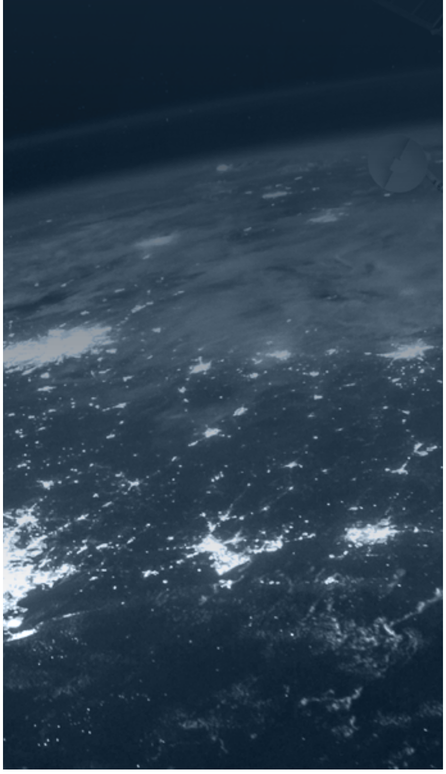
20 World Bank, 'Middle East & North Africa,' https://data.worldbank.org/country/ZQ

21 Organisation for Economic Co-operation and Development, 'The OECD in the Middle East and Africa,' www.oecd.org/mena/

Supply-chain Stakeholders

Key points

- The supply chain includes organisations that can be characterised as private or public sector, including satellite owners and operators, cloud companies, software providers, and analytics and solution providers.
- Globally and in MENA there are well-established players that provide satellite applications for the green economy.



Stakeholders in the satellite applications sector

Private Suppliers and Public Suppliers represent most of the supply chain for satellite applications for the green economy.

Private Suppliers are a diverse group that is further subdivided:

- **Satellite Operators & Resellers**, such as Inmarsat (SatComms) and Maxar (EO), own and operate satellites and sell data streams from them, either directly or via resellers.
- **Cloud Computing Providers**, such as Google Cloud Platform, Amazon Web Services (AWS), and Microsoft Azure, make it possible to process data into products by providing on-demand cloud infrastructure.
- **Platform/Solution Providers**, such as Ecometrica, build satellite applications that address specific green economy use cases.
- **Hardware/Software Suppliers** include Garmin GPS for navigation and companies that build large, commercial, geosynchronous satellite platforms, e.g., Airbus Defence and Space and Thales Alenia Space. There are also suppliers that specifically focus on smaller 'micro' and 'nano' satellites, such as Blink Astro, LLC and ClydeSpace. Some suppliers also manufacture satellite terminals to receive signals from satellites, such as Orbcomm.

Public Suppliers include two subgroups:

- **Satellite Operators** includes government space agencies such as the European Space Agency (ESA) (on behalf of the European Commission) which operates the Copernicus constellation.[22]
- **Analytics Providers**, such as mapping agencies, statistical bureaus, and land ministries, use satellite data alongside other data sources to create and contribute analyses and reports.

Finally, **Academia** plays roles in both the supply chain as data providers and as demand-side users. Academic institutions lead the development of methods required to extract satellite data to develop products, which they often make publicly available for further use.

22 European Union, 'Copernicus,' www.copernicus.eu/en. The EU's Earth Observation Programme, looking at our planet and its environment for the ultimate benefit of all European citizens, offers information services based on satellite EO and in-situ (non-space) data.

Stakeholders in MENA

The MENA region encompasses a variety of countries and cultures that make this geographical area highly heterogeneous. Countries in MENA are at varying levels of evolution of their domestic space industries. Some countries have strong space programmes and national space agencies, whilst others are less advanced. Nevertheless, it is possible to outline a general and non-exhaustive overview of the stakeholders that are part of the supply chain providing satellite applications to foster a green economy.

MENA Private Suppliers, as seen above, are a group that includes several subcategories:

- **Satellite Operators & Resellers** consider MENA as a key market, given the region's low connectivity rates. The leading company, Eutelsat (SatComms), which has offices in Amman and Dubai, offers services to both private and government customers, working with local operators. Whilst foreign-owned satellite operators like Eutelsat hold 60% of the market share, local operators like Arabsat, Nilesat, and Yahsat cover more than 30%.[23] The size of the small satellite market is also growing. In fact, governments are implementing various initiatives to upgrade communication, navigation, and remote-sensing applications by launching small satellites into orbit. The main growth regions in this sector are the UAE and Saudi Arabia, which support suppliers with ad hoc investments and programmes. However, it is also worth mentioning Kuwait, where the Orbital Space company, which launched the country's first private satellite in 2021, is reviving interest in the sector. Although the military market remains a leading segment of the overall small satellite market in the MENA region, the commercial segment is gaining momentum.[24]
- **Cloud Computing Providers** are enjoying success in the region, especially following the COVID-19 pandemic and government spending on smart city projects and the digitisation of public administration. Global giants such as AWS and Microsoft Azure are being joined by local cloud computing providers, such as BIOS Middle East, and data centres, such as Moro Hub, a subsidiary of Dubai Electricity & Water Authority supporting their Space-D programme. However, despite these developments, cloud spending in the MENA region remains lower than in other global regions, due to a lack of technical expertise.[25] Local data centres for cloud services mitigate this issue (see section Barriers to uptake of satellite applications for green economy).
- **Platform/Solution Providers** build satellite applications using a variety of techniques, including image analysis, geographic information systems (GIS), and machine learning/AI for data-intensive applications. Space Imaging stands out as a leading imagery and GIS solutions provider in the region for more than twenty years. Although its major clients are national and municipal entities, its services also extend to private companies. 4 Earth Intelligence (4EI) is also a major provider of applied analytics working in both Europe and the Middle East. However, there are several private companies working in the field of GIS and EO, such as Geomatic (Morocco) and GeoEyes (Egypt).[26] Geomatic is very active in many MENA countries, serving both national and international organisations, governments, private companies, NGOs, and academia in different fields of activities related to the green economy.
- **Hardware Providers** include companies like Ruptela, a telematics company providing solutions for fleet management and GPS tracking, which set up its new office in Dubai in 2021, and Taqnia Space, a leader in manufacturing satellite terminals. Finally, among the **Software Providers**, Telnet Holding is an important company to consider, as it is present in both Tunisia and Saudi Arabia and specialises in software and hardware engineering.

MENA Public Suppliers include two distinct subgroups:

- **Satellite Operators** include the national space agencies, of which the most advanced in the region is the United Arab Emirates Space Agency (UAESA). According to the *State of Green Economy Report 2016*, *"the UAE Space Agency strongly believes in the value of a sustainable green economy and aerospace activities not only benefit the UAE, but all humankind, whether for us living now or for future generations to come."*[27] The other major public space player in the UAE is the Mohammed Bin Rashid Space Centre (MBRSC), which has launched three EO satellites. Other MENA countries also have

23 Omar Nikam, 'The Middle East and African Satellite Market,' Satellite Market & Research, 3 May 2021, http://satellitemarkets.com/news-analysis/middle-east-and-african-satellite-market

24 6wresearch, *Middle East and Africa Small Satellite Market*, 2019–2025, September 2019, www.6wresearch.com/industry-report/middle-east-and-africa-small-satellite-market-2019-2025

25 Cristina Lago, 'Cloud Computing in the Middle East: The Next Big Tech Market?', CIO, 17 April 2021, www.cio.com/article/3408018/cloud-computing-in-the-middle-east-the-next-big-tech-market.html

26 Geomatic, 'About,' www.geomatic.ma/en/about-geomatic

27 World Green Economy Summit, *State of Green Economy Report 2016*, October 2016, https://dcce.ae/publications/state-of-green-economy-report-2016/

government space agencies; many have launched their own satellites, including Egypt, Algeria, Iran, Israel, and Saudi Arabia. Egypt and Algeria are the most active countries in the North African region. For example, even though the Egypt Space Agency was created only in 2019, there was already an important authority, the National Authority for Remote Sensing and Space Sciences (NARSS), that promoted the use of space technology for the country's development. In fact, it is very common in this region for countries without space agencies to have research centres set up under ministries that promote space activities. This is the case of the Royal Centre for Remote Sensing (CRTS) in Morocco. Also, there is interest in the creation of a Kuwaiti Space Agency.[28] However, there are still several countries in this region that do not have a national space programme.

- **Analytics Providers** include the Department of Geographical Information System Centre (GISC) in Dubai, whose services include the provision of digital maps in various formats, depending on the requests and requesting entities, and the Royal Jordanian Centre, with similar characteristics. Others include Saudi Arabia's General Authority for Survey and Geospatial Information, Qatar's Centre for Geographic Information Systems (CGIS), and Oman's National Survey Authority (NSA).

Regarding **Academia**, MENA countries boast the presence of universities and research institutes that provide studies about using satellite applications for some of the domains this report addresses. Examples include United Arab Emirates University (UAEU), which also offers a Master of Science in Remote Sensing and Geographic Information Systems, and the Research Institute of Sciences and Engineering (RISE), with its Geographic Information System and Remote Sensing Center. Furthermore, Kuwait University is working on the country's first satellite project, scheduled to be launched in 2022, with the aim of training students to build satellites for the benefit of humanity.[29]

Finally, some **NGOs** and **Development Banks** provide training and funding for implementing innovative projects through satellite applications for sustainable development and, therefore, for the green economy. Among NGOs, the UN Regional Centers in Morocco and Jordan and the Sahara and Sahel Observatory (OSS) are very active in the fight against climate change. A significant example among the Development Banks is the collaboration between the Islamic Development Bank (IsDB) and the Global Partnership for Sustainable Development Data aimed at testing the use of satellite imagery to provide timely data to inform environmental protection policies in Senegal.[30]

Table 1 identifies these supply-chain stakeholder groups with examples globally and from MENA.

28 SpaceWatch Global, 'Calls Grow for the Creation of a Kuwaiti Space Agency,' https://spacewatch.global/2017/03/calls-grow-creation-kuwaiti-space-agency/

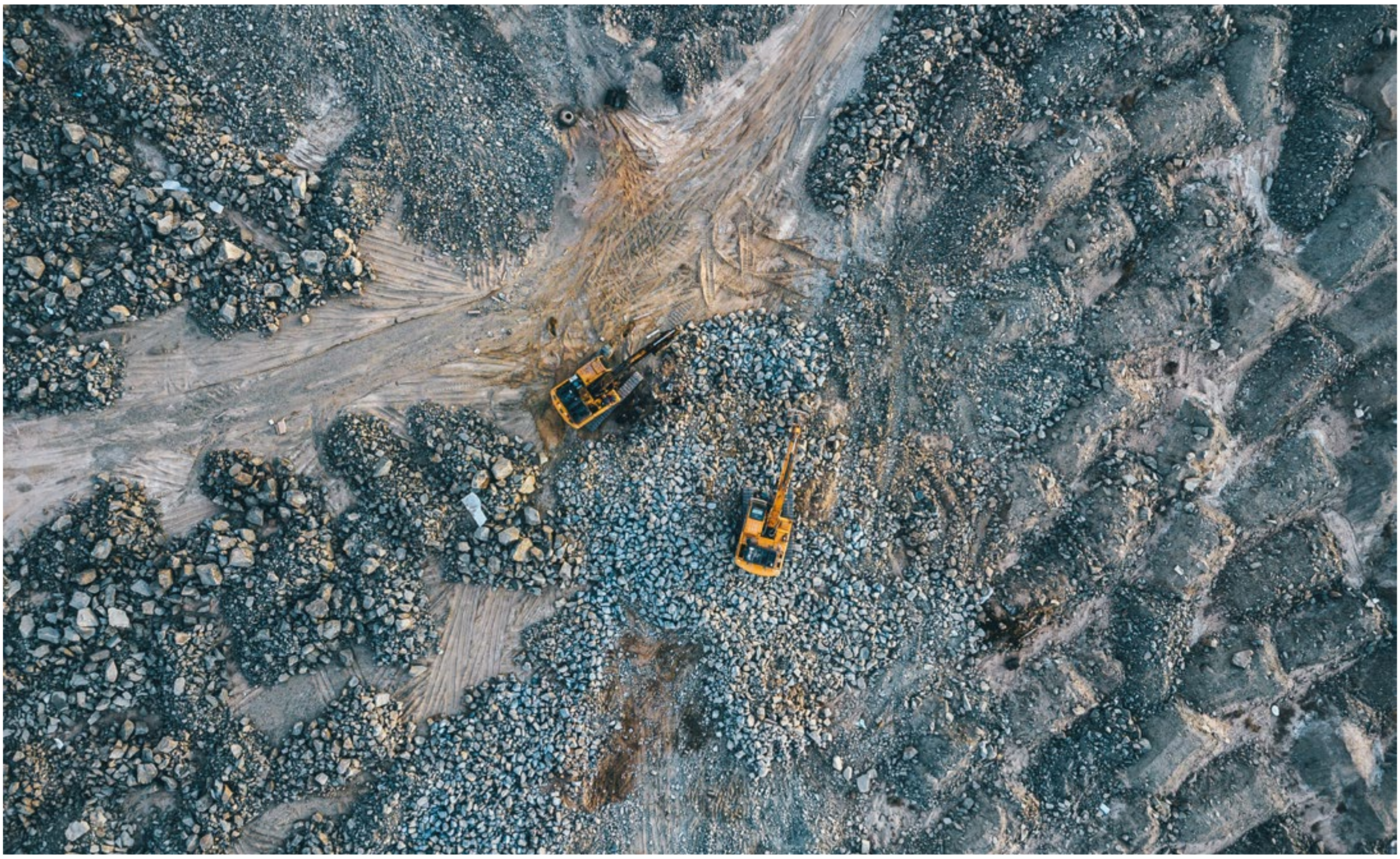
29 Kuwait News Agency, 'Kuwait University displays "first national satellite" at Expo 2020 Dubai,' www.kuna.net.kw/ArticleDetails.aspx?id=3005719&language=en#

30 Islamic Development Bank, *The Road to the SDGs: The President's Five-Year Programme, Progress and Achievements*, 2021, www.isdb.org/sites/default/files/media/documents/2022-02/The%20Road%20to%20the%20SDGs%20English%202.pdf

Table 1: Supply-chain stakeholder groups globally and in MENA

Stakeholder Group	Subgroup	Global Examples	MENA Examples
Private Suppliers	**Satellite Operators and Resellers**	Airbus, Capella Space, Earth-i, Planet Labs, Inmarsat, Maxar Technologies, OneWeb, Satellogic, Head Aerospace	Eutelsat MENA, Arabsat, Es'hailSat, Nilesat, Yahsat, Thuraya
	Cloud Computing Providers	Alibaba Cloud, AWS, Google Cloud Platform, IBM Cloud, Microsoft Azure, Oracle, Salesforce, SAP Cloud Platform	BIOS Middle East, AWS Middle East, Khazna, Moro Hub, eHDF
	Platform/ Solution Providers	*Open access platforms:* GEE, Microsoft Planetary Computer Ecometrica, Orbital Insight, Descartes Labs, CrowdAI, SpaceKnow, Astraea	Space Imaging Middle East, 4 Earth Intelligence, GISCON Middle East, EOMAP ME, Transport Hi-Tech Consultants, TruKKer, GIS4DS, Geomatic (Morocco), One View (Israel), Geospatial Integrated Solutions, GeoEye, GeoMAP (Egypt), GIG (Egypt)
	Hardware/ Software Suppliers	*Hardware:* Garmin, Thales Alenia Space, Gilat Satellite Networks, Harris CapRock, ViaSat, Airbus, ClydeSpace *Software:* Harris (ENVI), ESRI, PCI Geomatica *Open access:* QGIS *Satellite terminals:* Orbcomm	*Hardware:* Ruptela MENA *Software:* ESRI Middle East, e-SoftSat, Telnet Holding *Satellite terminals:* Taqnia
Public Suppliers	**Satellite Operators**	European Space Agency (ESA), National Aeronautics and Space Administration (NASA), Japan Aerospace Exploration Agency (JAXA)	United Arab Emirates Space Agency (UEASA), Mohammed Bin Rashid Space Centre (MBRSC), Algerian Space Agency (ASAL), Israeli Space Agency (ISA), Egyptian Space Agency, National Authority for Remote Sensing and Space Sciences (NARSS Egypt), Agence Spatiale Algérienne (ASAL), Iranian Space Agency, Royal Centre for Remote Sensing (CRTS-Morocco)
	Analytics Providers	*Mapping agencies:* Geoscience Australia, UK Ordnance Survey *Innovation units:* UK Satellite Applications Catapult *Statistical offices:* UK Office for National Statistics, National Bureau of Statistics	*Mapping agencies:* Abu Dhabi Digital Authority (ADA-UAE), General Authority for Survey and Geospatial Information (GASGI-Saudi Arabia), National Survey Authority (NSA-Oman), Centre National de la Cartographie et de la Télédétection (CNCT-Tunisia), Centre Royal de Télédétection Spatiale (CRTS-Morocco), Royal Jordanian Geographic Centre (Jordan) *Innovation units:* National Space Science and Technology Center (NSSTC-UAE) *Statistical offices:* National Centre for Statistics and Information (NCIS-Oman)
Academia	Chatham House, The Renewable Energy Institute		King Abdullah University of Science and Technology (KAUST-Saudi Arabia), United Arab Emirates University (UAEU), Research Institute of Sciences and Engineering (RISE-UAE), University of Dubai (UAE), African Geospatial Sciences Institute (AGSI), Kuwait College for Science and Technology (KCST), Asher Space Research Institute (ASRI-Israel) Khalifa University of Science and Technology (UAE), Ibn Zohr University (Morocco)
NGOs	*International NGOs:* Organisation for Economic Co-operation and Development (OECD), International Renewable Energy Agency (IRENA), Green Growth Knowledge Partnership (GGKP), Global Green Growth Institute *UN agencies:* United Nations Development Programme (UNDP), United Nations Environment Programme (UNEP), United Nations Industrial Development Organization (UNIDO)		*International NGOs:* Sahara and Sahel Observatory (OSS) *UN agencies:* African Regional Centre for Space Science and Technology Education (CRASTE-LF-Morocco), Regional Centre for Space Science and Technology Education for Western Asia (RCSSTEWA-Jordan)
Development Agency	*International Financial Institutions:* World Bank, Asian Development Bank		African Development Bank, Islamic Development Bank (IDB)

Demand-chain stakeholders



Key points

- There is a diverse community of users of satellite applications for the green economy, including government, private sector, development agencies, media, academia, and NGOs.
- In MENA countries there are many governmental entities, such as ministries, authorities, and public companies, that are potential users of satellite applications for a green economy.

Stakeholders of green economy domains

There is a diverse community of users of satellite applications for the green economy.

Government includes senior members of government, such as ministers of specific departments. They liaise with other government agencies and lead teams overseeing analysts. Government also includes mapping agencies, e.g., UK Ordnance Survey or Survey of India. They provide other parts of government with analyses to support decision-making.

Private Sector includes a wide range of companies within domains of urban, transport, waste, energy, extractives and industry, and tourism. There are also companies that cut across all domains, such as insurance/reinsurance and engineering firms.

Development Agencies include bilateral and multilateral donors, international financial institutions (IFIs), private foundations, and corporate philanthropies. They provide funding and assistance to the government, NGOs, and the private sector.

Media includes local and international journalists. They report on green economy issues to the broader public.

Academia plays roles on both the supply chain as data providers and as demand-side users.

NGOs include local and international NGOs focused on green economy issues.

Stakeholders in MENA

As stated earlier, the MENA region is comprised of very different countries. However, one feature they have in common is the presence of many public or government-backed entities in the domains of this report (e.g., energy companies). Regarding the **Government** group, municipalities and environment agencies are the biggest stakeholders from a user-side perspective; as public authorities, they also have an important sphere of influence on initiatives taken at government level, impacting the work of other government agencies. Some examples in the UAE are: the Dubai Electricity & Water Authority (DEWA), the sole provider of electricity and water in the Emirate of Dubai that issues an annual sustainability report with a focus on DEWA's efforts in promoting sustainability with its social, economic, and environmental aspects;[31] the United Arab Emirates Government, which launched the Green Economy Initiative in 2012 with the aim of improving the country's sustainability by becoming a centre of export and import of green products and technology;[32] the Abu Dhabi Department of Municipalities and Transport (DMT), which is responsible for urban and transportation planning; and the Abu Dhabi Environment Agency, the largest environmental regulator in the Middle East. Other examples in the MENA region include the National Agency for Energy Conservation of Tunisia, supervised by the Ministry of Energy and Mines, that promotes energy efficiency, renewable energy sources, and alternative energy sources, and the National Office of Hydrocarbons and Mines in Morocco, a pioneer in Environmental Impact Assessment (EIA). Other relevant governmental entities are state-owned oil and gas companies, such as the Saudi Arabian Oil Company (ARAMCO) and Petroleum Development Oman (PDO), which both aim to drive energy efficiency and address the global emissions challenge.[33]

The **Private Sector** includes several companies that deal with urban planning, waste management, transport, energy and mining, and tourism. One example is KEO International Consultants, a planning, design, engineering, and project management company committed to establishing and maintaining the highest standards of health, safety, and environmental management. Waagner Biro Bridge Services (Dubai) is a bridge construction and maintenance company that takes responsibility for the impact of its operational activities, especially in the field of environmental protection and sustainability.[34] Finally, Smart Energy Solutions (SES) is a private power supplier serving temporary and medium-term energy needs across MENA.[35]

Other potential users of satellite services could be:

- **Media,** both local and regional, such as Al Jazeera, that may use them to raise awareness of the public.
- **Academia** that want to conduct research and feasibility studies about innovative satellite technology for green economy projects.
- **NGOs**, such as WGEO itself or the Arab Forum for Environment and Development, and Development Agencies, such as the African Development Bank, that employ satellite data to empower their activities and work.

Table 2 identifies these demand-chain stakeholder groups with examples globally and from MENA.

31 Dubai Electricity & Water Authority, 'DEWA Issues its 8th Sustainability Report,' 30 August 2021, www.dewa.gov.ae/en/about-us/media-publications/latest-news/2021/08/dewa-issues-its-8th-sustainability-report

32 Government of the United Arab Emirates, 'Green Economy for Sustainable Development,' updated 20 April 2021, https://u.ae/en/about-the-uae/economy/green-economy-for-sustainable-development

33 Saudi Arabian Oil Company, 'Who We Are,' www.aramco.com/en/

34 Waagner Biro Bridge Services, 'Company,' https://waagnerbiro-bridgeservices.com/why-waagner-biro/

35 Smart Energy Solutions, 'About Us,' www.sesrent.com/aboutus.php

Table 2: Demand-chain stakeholder groups globally and from MENA

Stakeholder Group	Global Examples	MENA Examples
Government	Ministers Ministries responsible for transport, urban, waste, energy, extractives and industry, and tourism Nationally owned companies including utility, water, and energy companies Mapping agencies: UK Ordnance Survey, Survey of India	United Arab Emirates Government (UAE) Abu Dhabi Department of Municipalities and Transport (DMT-UAE), UAE Ministry of Energy and Infrastructure (UAE), Ministry of Energy and Mines (Tunisia), National Agency for Energy Conservation (ANME-Tunisia), National Office of Hydrocarbon and Mining (Morocco), Abu Dhabi Environment Agency (UAE) Saudi Arabian Oil Company (ARAMCO-Saudi Arabia), Abu Dhabi National Oil Company (ADNOC-UAE), Petroleum Development Oman (PDO-Oman), Masdar Clean Energy (UAE), Qatar General Electricity & Water Corporation (KAHRAMAA-Qatar), OCP Group (Morocco)
Private Sector	***Urban:*** urban planning companies, architects, property companies ***Transport:*** rail/road network operators, road/highway maintenance companies ***Waste:*** processing and recycling companies ***Energy, extractives, and industry:*** mining or oil/gas companies, renewable energy companies, power utilities, independent power producers ***Tourism:*** tourism venues/operators ***Insurance companies:*** Swiss Re, Munich Re Engineering companies	***Urban:*** KEO International Consultants (several locations in MENA), Omran architects ***Transport:*** Agility, Emirates Logistics, Saadat Sorat (Iran), Waagner Biro Bridge Services (Qatar) ***Waste:*** Bee'ah (UAE), Suez Middle East Recycling LLC (SMER-UAE) ***Energy, extractives, and industry:*** Raban Al-Safina (UAE), Smart Energy Solutions (several locations in MENA), Ma'aden (Saudi Arabia) ***Insurance companies:*** Harel Insurance Investments & Finance Services (Israel) Taka Solutions (UAE)
Development Agency	***Bilaterals and Multilaterals:*** Global Environment Facility, Norway International Climate and Forestry Initiative (NICFI), Germany's GIZ, Foreign, Commonwealth and Development Office (UK FCDO) ***IFIs:*** World Bank, Asian Development Bank, International Development Bank (IDB) ***Private foundations:*** Rockefeller Foundation, Ford Foundation, Hewlett Foundation	***International Finance Institutions:*** Islamic Development Bank (IsDB), Arab Bank for Economic Development in Africa (BADEA) ***Private foundations:*** Jordan Renewable Energy and Energy Efficiency Fund (JREEEF), Clean Technology Fund (CTF)
Media	***Local journalists:*** Associated Press ***International journalists:*** *The Guardian*, Al Jazeera, Devex	Gulf News, The National, Arab News, Egypt Independent, Azzaman, Al-Alam
Academia	See examples in Table 1	See examples in Table 1
NGOs	See examples in Table 1	WGEO, Arab Forum for Environment and Development, EDAMA, EcoMENA, League of Arab States (LAS), Royal Scientific Society Jordan (RSS), Jordan Environment Society (JES)

Satellite application use cases and examples

Key points

- 28 use cases for satellite applications have been identified across urban (10), transport (3), waste (4), energy, extractives, and industry (7), and tourism (4).
- 19 case studies are provided from the global regions and MENA to highlight a range of different satellite applications and their benefits.

Definition of the green economy

Satellite applications can support a green economy that is low carbon, resource efficient, and socially inclusive. Across the domains of urban, transport, waste, energy, extractives, and industry, and tourism, satellite applications support a spectrum of use cases, as illustrated in Figure 4. This section details the use cases and satellite applications examples for each domain across the world and in MENA.

Figure 4: Satellite application use cases and outcomes for green economy domains

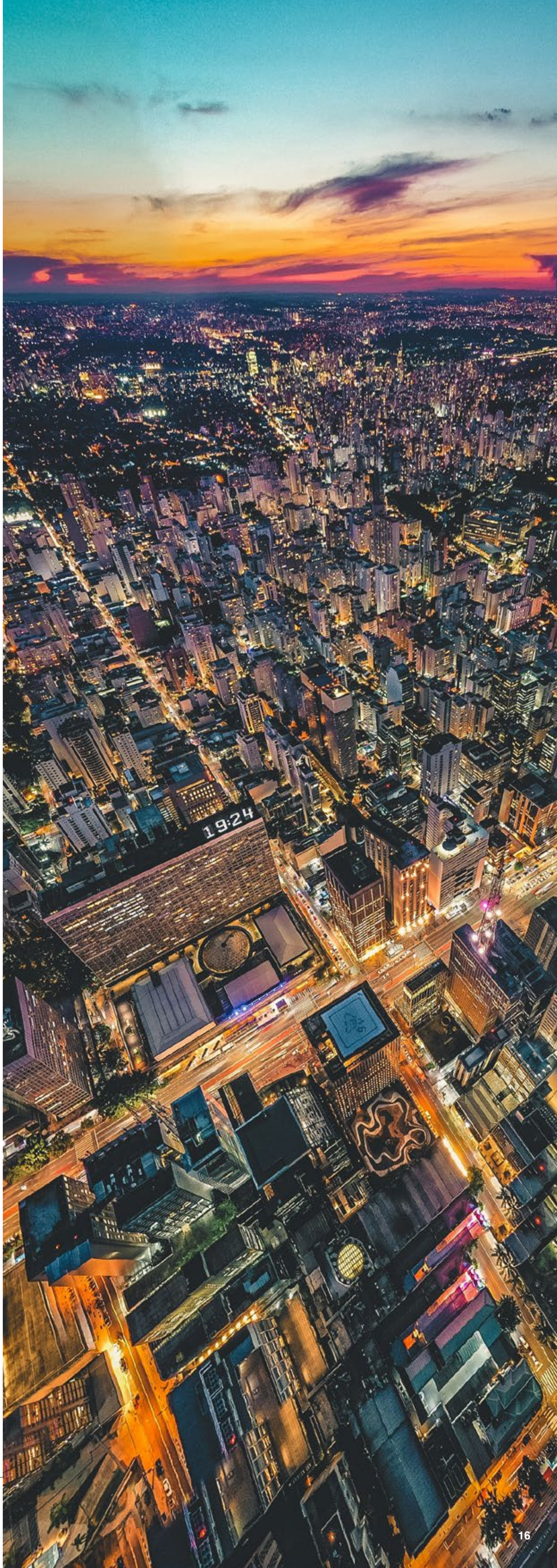
IMPACT	A green economy that is low carbon, resource efficient and socially inclusive				
SUB-IMPACT	Investing in energy and resource efficiency				
DOMAINS	Urban	Transport	Waste	Energy, extractives & industry	Tourism
OUTCOMES	Cities fostering economic growth whilst minimising environmental damage	Reducing the environmental footprint of transport and investing in low-carbon infrastructure	Minimisation of material use and waste whilst maximising recycling	Reducing the environmental impact of energy & industry through resource efficiency, carbon-saving investments, and regulatory compliance	Fostering jobs and economic growth whilst reducing associated greenhouse emissions and damage to natural ecosystems
SATELLITE APPLICATIONS	Apps for mapping urban extent, density and growth, air pollution, infrastructure reconstruction, and waste disposal sites	Apps for mapping infrastructure investment, traffic monitoring, and connectivity & mapping for autonomous transport	Apps for managing waste collection processes, including monitoring waste disposal sites	Apps for design, construction and operation of assets, detecting land & sea industrial pollution, industrial, environmental & regulatory compliance	Apps for mapping cultural sites, assessment of environmental damage, establishment of ecotourism, and providing near real-time advice to tourists

Urban

Satellite applications support city planners and relevant authorities in sustainable urban development. They provide information for urban planning by mapping the extent and density of the urban environment and growth over time. Environmental issues are addressed by monitoring green areas (e.g., parks) and conversely waste sites. Cities pose risks to human health; satellite applications help mitigate this through monitoring of air pollution/quality and identifying urban heat islands and heat hazards. Municipal governments are responsible for many land administration processes, including maintaining land ownership cadastres,[36] supporting land and property valuation and ownership, and applying and collecting taxes. Satellite applications can also identify and monitor growth in informal settlements and assess their needs, e.g., water and sanitation infrastructure.

Table 3: List of use cases for urban

Use Case	Domain-Specific Examples
Urban extent, density, and growth	Extent of urban footprint and its growth over time Density of buildings and population
Urban green areas	Identifying riverine habitats, woodlands, hedges, trees, as well as public parks, private gardens, forested areas
Air pollution and quality	Pollution information and alerts for citizens Testing the impact of environmental interventions
Urban heat islands and heat hazards	Extreme heat alerts for citizens Improved city design to minimise urban heat islands
Land administration and taxation	Property valuation and taxation Producing land ownership/cadastral maps
Informal settlements/slums	Identification and delineation of slums Needs assessment for services such as water and sanitation
Subsidence and erosion	Warnings about potential infrastructure instability Prioritising and reinforcing engineering projects to address hazards
Early warning systems	Assessment of various urban hazards risks (flood, landslide, and subsidence) and facilitating early warnings
Infrastructure reconstruction	Evidencing progress of infrastructure reconstruction Increasing infrastructure resilience
Infrastructure mapping and exposure	Mapping of transport infrastructure, e.g., roads, rail, ports Quantifying financial exposure of assets



36 Wikipedia, 'Cadastre,' https://en.wikipedia.org/wiki/Cadastre

Earth Observation for Sustainable Development–Urban Development (EO4SD-Urban)

GEOGRAPHY
15 countries

SUPPLIER
GAF AG & partners[37]

USE CASE
Multiple

SATELLITE APPLICATION
EO

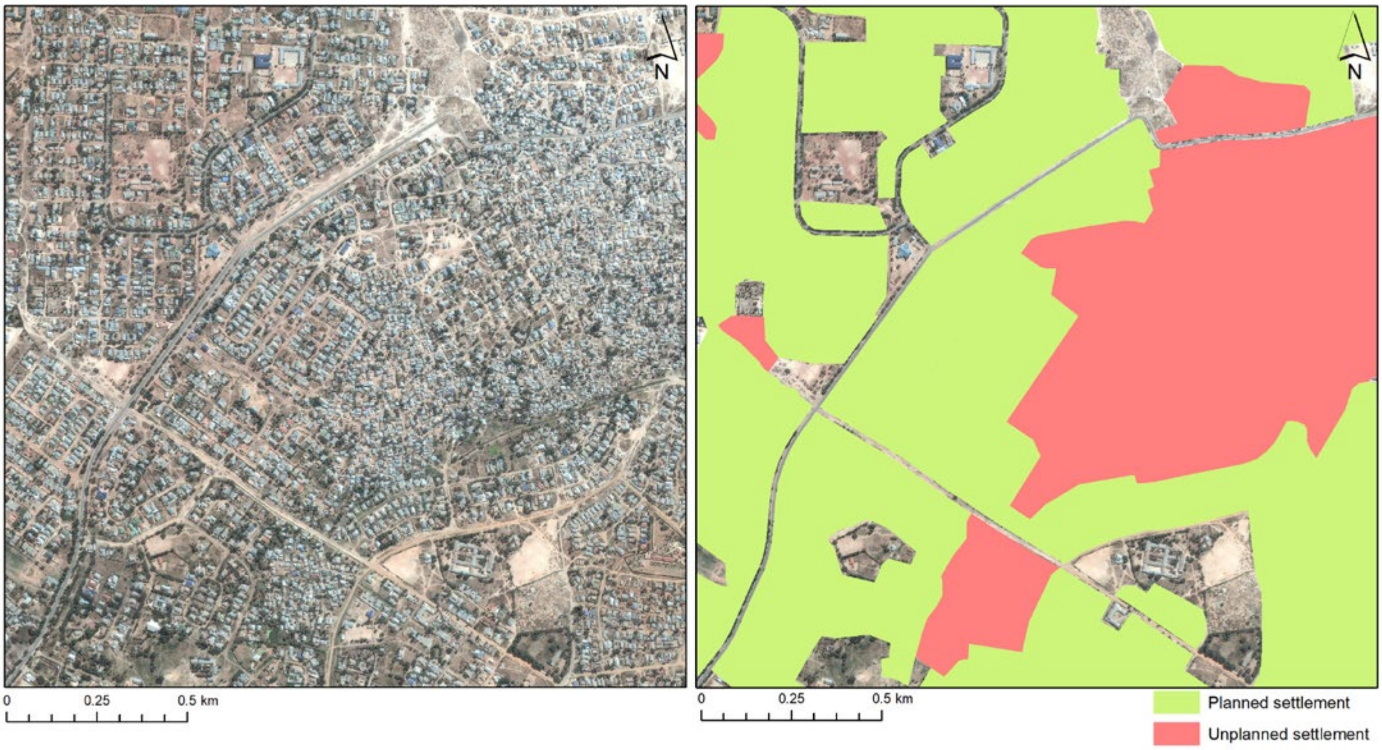
DESCRIPTION

EO4SD is a programme from ESA that aims to integrate satellite applications into the planning and implementation of development programmes with IFIs, including the World Bank and Asian Development Bank (ADB). EO4SD-Urban ran from 2016 to 2019 and provided satellite applications to 31 unique cities across 15 countries.

BENEFITS AND OUTCOMES

- Cost-effective method for delineating and assessing the needs of slum populations.
- Enabled cities to assess the risk of flooding in housing development decisions.
- Time savings for municipal government staff conducting diagnostics of city infrastructure, future urban development plans, and property valuations for taxation.
- World Bank and ADB used EO4SD-Urban products as powerful communication tools with government urban planning departments.

Figure 5: Informal settlements mapped in Dodoma, Tanzania



Credit: GAF AG. Satellite Imagery: Pleiades © (2016) CNES, Distribution AIRBUS DS, spatial resolution between 0.3m and 1m

37 Consortium members included: GAF AG, Caribou Space, Systemes d'Information a Reference Spatiale (SIRS), GISAT, Egis, the German Aerospace Centre (DLR), NEO, JOANNEUM RESEARCH, and GISBOX.

DMSat-1

GEOGRAPHY
UAE

SUPPLIER
Dubai Municipality

USE CASE
Air pollution/quality

SATELLITE APPLICATION
EO

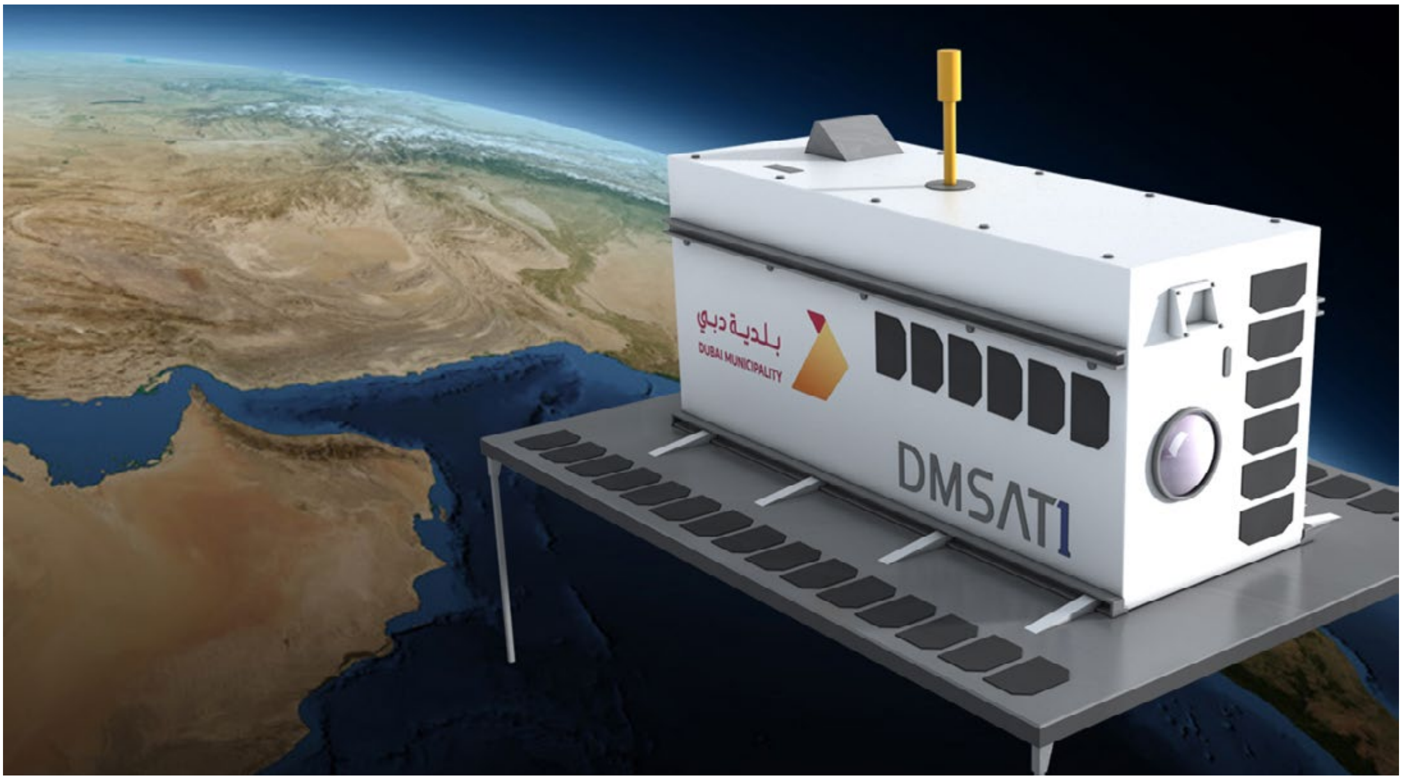
DESCRIPTION

On 20 March 2021, the Dubai Municipality launched DMSat-1, a microsatellite built by the University of Toronto's Space Flight Laboratory (SFL) in collaboration with the MBRSC, which will handle data collection and processing operations. The primary objective of DMSat-1 is to monitor air quality by measuring air pollutants and greenhouse gases, and creating maps of the concentration and distribution of greenhouse gases in Dubai and the UAE. The two instruments on board the satellite enable it to monitor both greenhouse gases, such as carbon dioxide and methane, and the aerosols usually present in the upper atmosphere and often caused by anthropomorphic sources, but also by dust storms. The data provided by the satellite is managed by the MBRSC; once processed by artificial intelligence systems, it will be provided to the Dubai Municipality.[38]

BENEFITS AND OUTCOMES

- Construction of a spatial database of air pollutants and gases causing climate change to assess the environmental situation and make informed decisions on green economy and low-carbon development strategies.
- Use of results to develop sustainable urban planning and land-use strategies in the city.
- Study of air pollutant concentrations and public health impacts to find ways of tackling them by ensuring a healthy and productive ecosystem.

Figure 6: Artistic representation of DMSat-1



Credit: Government of Dubai[39]

38 Nianhua Liu, 'Monitoring Aerosol and Greenhouse Gas, Dubai Municipality Announces Launch of DMSat-1 Atmospheric Monitoring Microsatellite built by Space Flight Laboratory,' GeoAwesomeness, 5 April 2021, https://geoawesomeness.com/monitoring-aerosol-and-greenhouse-gas-dubai-municipality-announces-launch-of-dmsat-1-atmospheric-monitoring-microsatellite-built-by-space-flight-laboratory/

39 Government of Dubai, 'About DMSat-1,' www.dubaiairenvironment.dm.gov.ae/dmsat_1

Earth Observation for Sustainable Development–Urban Development (EO4SD-Urban)

GEOGRAPHY
Iraq

SUPPLIER
GAF AG

USE CASE
Urban extent, density, and growth; urban green areas

SATELLITE APPLICATION
EO

DESCRIPTION

This project is part of ESA's EO4SD initiative in cooperation with the World Bank. EO supported, in this case, two of the institution's programmes, "Urban Spaces for City Transformation" and "Emergency Operations for Development Project." In particular, the EO applications provided to the Iraqi cities of Ramadi and Fallujah were: Urban Extent, Land Cover Land Use, and Urban Green Areas, among others.

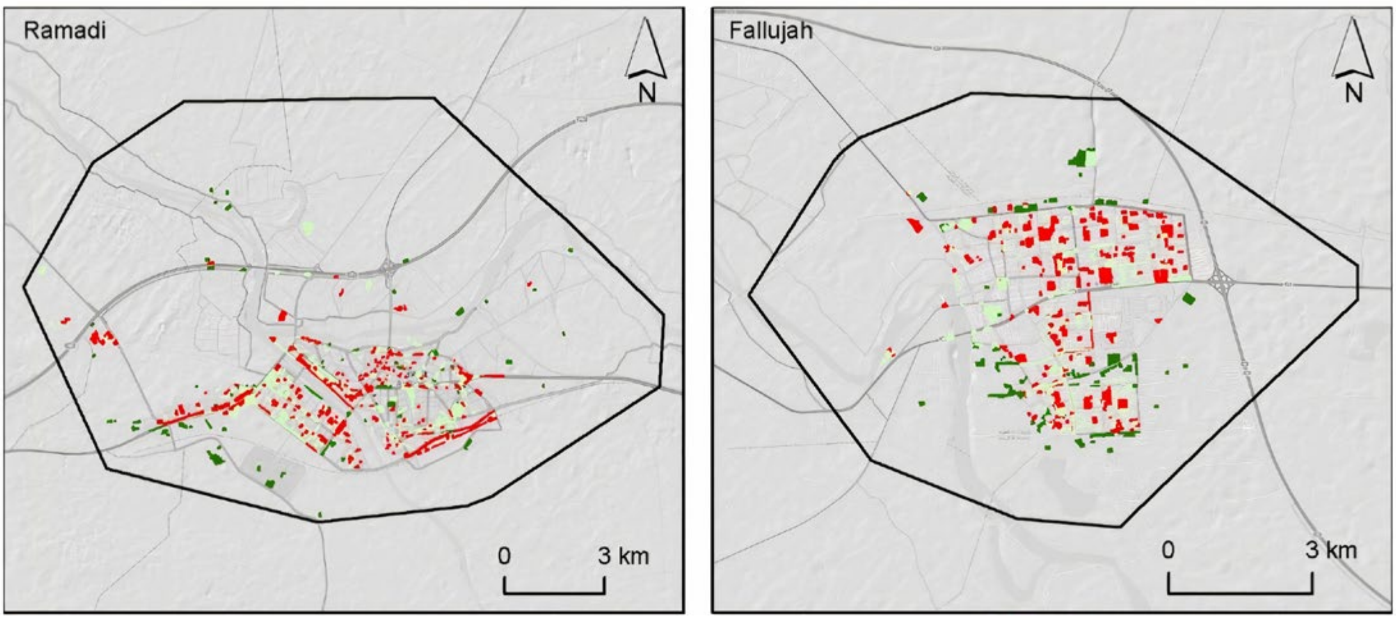
The Urban Extent application was used to assess the historical developments of the cities from 1985 to 2015. It showed that the main development is located on the edges of core cities and in the traditional villages surrounding Ramadi and Fallujah, while in the city centres there is only small expansion of urban fabric.

The Urban Green Areas application, on the other hand, provides indications of the spatial distribution of green and open spaces in the city centre, as inadequate and poorly designed spaces often lead to degradation of liveability in the urban environment. Analyses of Ramadi and Fallujah, for example, showed that there were large losses of open green areas between 2002 and 2017.[40]

BENEFITS AND OUTCOMES

- Examining the current urban situation and potential future development, with the opportunity to avoid threats to biodiversity.
- Transforming urban environments by promoting inclusive green growth.
- Improving liveability in cities in balance with environmental sustainability.

Figure 7: Changes of urban green areas, 2004–2017 (Ramadi) and 2002–2017 (Fallujah)



Credit: GISAT & GAF[41]

40 The World Bank, 'Fallujah (Iraq) – Transport Network (ESA EO4SD-Urban),' updated 21 October 2021, https://datacatalog.worldbank.org/search/dataset/0040286

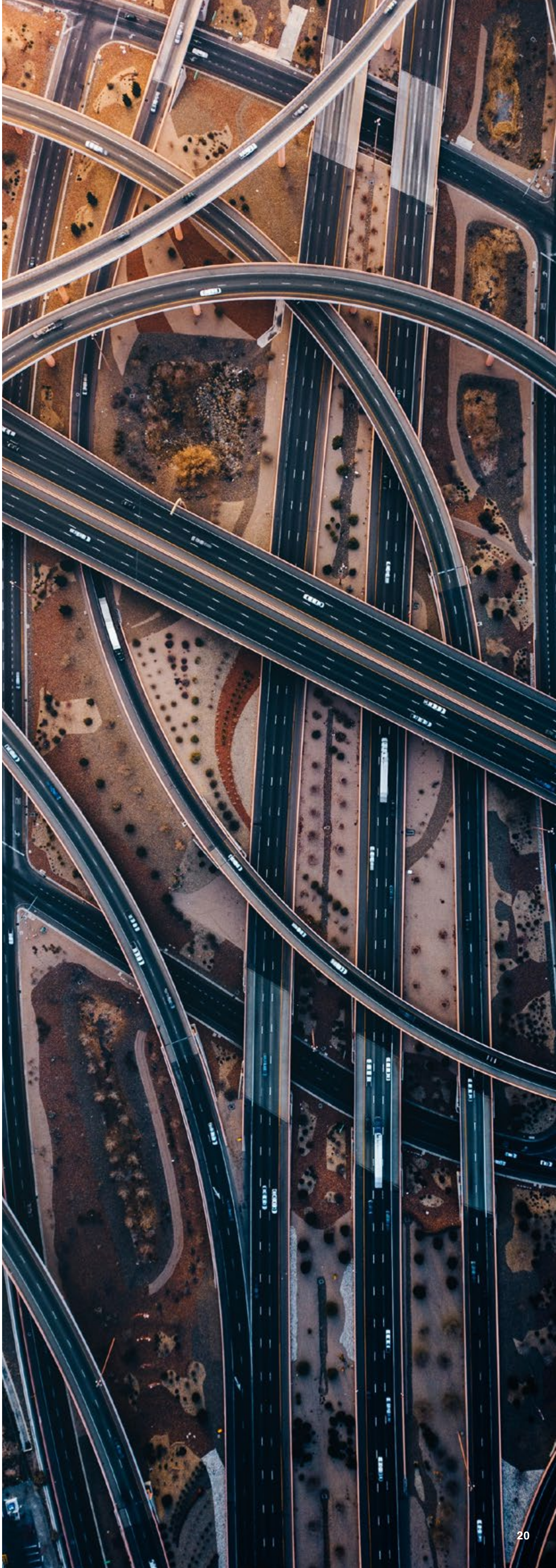
41 GAF AG, *EO4SD-Urban Project: Ramadi & Fallujah City Report*, 19 March 2019, https://development-data-hub-s3-public.s3.amazonaws.com/ddhfiles/583936/eo4sd-urban_ramadifallujah_operations_report_v2-0_inclqc.pdf

Transport

Satellite applications allow real-time monitoring of traffic conditions so traffic management systems can optimise traffic flow, reducing journey times and consequent emissions. Existing transport infrastructure can be monitored for maintenance needs by, for example, observing subsidence. Future transport infrastructure can be planned effectively, accounting for current and future growth patterns in population, urban infrastructure, and traffic. Satellite applications can support development of autonomous vehicles with very accurate, up-to-date maps of roads and ubiquitous, high-speed connectivity.

Table 4: List of use cases for transport

Use Case	Domain-Specific Examples
Traffic and vehicle monitoring	Optimising traffic flows Supporting real-time traffic management systems Traffic monitoring to inform urban planning and construction of new buildings or roads
Transportation infrastructure investment	Improved planning of future transport investment Monitoring and maintaining existing infrastructure, e.g., for subsidence
Connectivity and mapping for autonomous transport	Detailed mapping of roads and their features, e.g., lane markings and toll booths Ubiquitous, high-speed connectivity



Regional Navigation and Information System (RNIS)

GEOGRAPHY
Russia

SUPPLIER
Russian Government

USE CASE
Traffic and vehicle monitoring; transportation infrastructure investment

SATELLITE APPLICATION
GNSS

DESCRIPTION

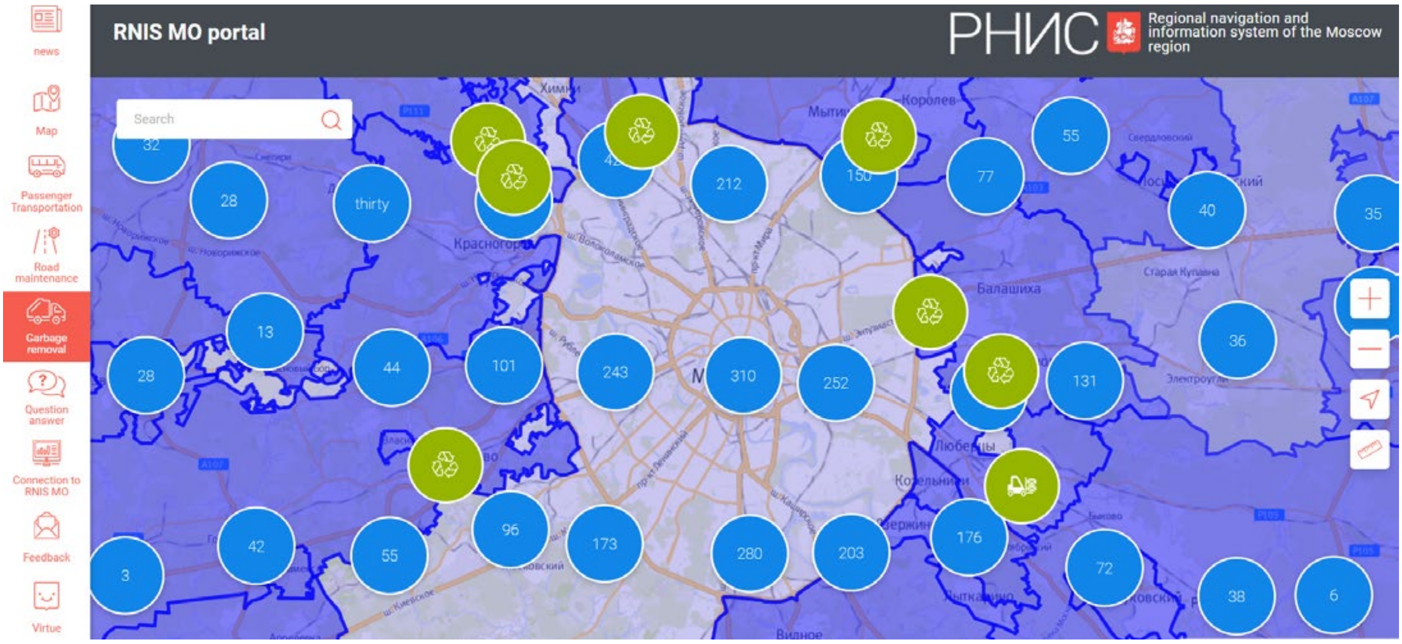
The use of GNSS technology, in particular GLONASS and GPS, has made it possible to implement the Regional Navigation and Information System (RNIS) in Russia. This system is designed to support the country's entire transport sector to increase efficiency and safety. RNIS is an integrated system that allows public transport to be monitored through knowledge of the location, condition, and movement of vehicles. All services are available to both transport companies and residents, with 24-hour access to information on bus routes, road repairs, and street cleaning.

The RNIS centralises several subsystems that are indispensable for the smooth operation of urban transport, such as the control of transit shipments and passenger transport, the monitoring of school buses, the management of ambulances, the road transport of special loads, and the monitoring of public service unit vehicles.[42]

BENEFITS AND OUTCOMES

- Improvements in the efficiency of public transportation management, thus encouraging its use and reducing private vehicle use and greenhouse gas emissions.
- Visualisation of the current situation resulting in an increase in the accuracy of forecasts to design integrated multiple transport modes (e.g., park-cycle-ride).
- Cost reductions for vehicle repairs, due to reduced incidents rate (up to 10%) and for fuel, due to the reduced traffic congestion (15% to 30%).
- Labour productivity growth of 30% by reducing time spent in traffic.

Figure 8: A screenshot from RNIS Moscow portal



Credit: PHNC[43]

42 Global Infrastructure Hub, 'Satellite Based Navigation to Optimize Traffic Flows,' 4 November 2020, https://cdn.gihub.org/umbraco/media/3183/7-satellite-based-navigation-to-optimize-traffic-flows-use-case-ltic.pdf

43 Regional Navigation and Information System of the Moscow Region, 'RNIS MO Portal: Garbage Removal,' https://portal.rnis.mosreg.ru/map/garbage

High-Definition (HD) Maps for Automated Driving

GEOGRAPHY
Japan

USE CASE
Connectivity and mapping for autonomous transport

SUPPLIER
Collaboration between Toyota Research Institute-Advanced Development (TRI-AD), Maxar Technologies, and NTT DATA

SATELLITE APPLICATION
EO

DESCRIPTION

This collaboration between TRI-AD, Maxar, and NTT DATA is aimed at developing a proof-of-concept for HD automated maps to advance the development of automated vehicles. Progress was significant, as the team created HD maps with an accuracy of 25cm for the entire city of Tokyo.

The algorithms created by NTT DATA used machine learning to extract information from satellite imagery provided by Maxar, which enabled the creation of a detailed road network that was then exploited by TRI-AD's Automated Mapping Platform. Automated vehicles use real-time sensors that need HD maps as a reference point to ensure safe driving.[44]

BENEFITS AND OUTCOMES

Automated HD maps can accelerate the development of automated driving systems, helping to:

- Reduce congestion by maintaining safe distance between vehicles and reducing the number of stop-and-go waves.
- Reduce crashes on roads and traffic deaths by 90%.[45]
- Reduce harmful emissions by 60%.[46]
- Improve fuel economy, reducing fuel amount wasted by 4%–10%.[47]
- Reduce travel time by 40% and generate savings of £20 billion in increased productivity.[48]
- Allow seniors and people with disabilities to enhance their independence.

Figure 9: Maxar satellite image (left), with automatic removal of automobiles (middle), and identification of road markings (right)

Credit: Maxar Technologies, spatial resolution of 0.23m[49]

44 Kevin Bullock, 'TRI-AD, NTT DATA and Maxar Successfully Create HD Map for Automated Driving,' MAXAR, 10 March 2020, https://blog.maxar.com/earth-intelligence/2020/tri-ad-ntt-data-and-maxar-successfully-create-hd-map-for-automated-driving

45 Thales, '7 Benefits of Autonomous Cars,' updated January 2021, www.thalesgroup.com/en/markets/digital-identity-and-security/iot/magazine/7-benefits-autonomous-cars

46 Ohio University College of Engineering, 'The Future of Driving,' 2 March 2021, https://onlinemasters.ohio.edu/blog/the-future-of-driving/

47 James M. Anderson et al., Autonomous Vehicle Technology: A Guide for Policymakers, RAND Corporation, 2016, www.rand.org/content/dam/rand/pubs/research_reports/RR400/RR443-2/RAND_RR443-2.pdf

48 KPMG, Connected and Autonomous Vehicles: The UK Opportunity, March 2015, https://assets.kpmg/content/dam/kpmg/images/2015/05/connected-and-autonomous-vehicles.pdf

49 Kevin Bullock, 'TRI-AD, NTT DATA and Maxar Successfully Create HD Map for Automated Driving,' MAXAR, 10 March 2020, https://blog.maxar.com/earth-intelligence/2020/tri-ad-ntt-data-and-maxar-successfully-create-hd-map-for-automated-driving

Traffic management system

GEOGRAPHY
UAE and the Kingdom of Saudi Arabia (KSA)

SUPPLIER
Transport Hi-Tech Consultants (THTC)

USE CASE
Traffic and vehicle monitoring

SATELLITE APPLICATION
GNSS and EO

DESCRIPTION

THTC provides intelligent mobility services using digital maps, GIS, and intelligent transport. It has been working with various stakeholders across the Middle East, thanks in part to data provided by TomTom, and has delivered several successful projects in the UAE and the KSA.

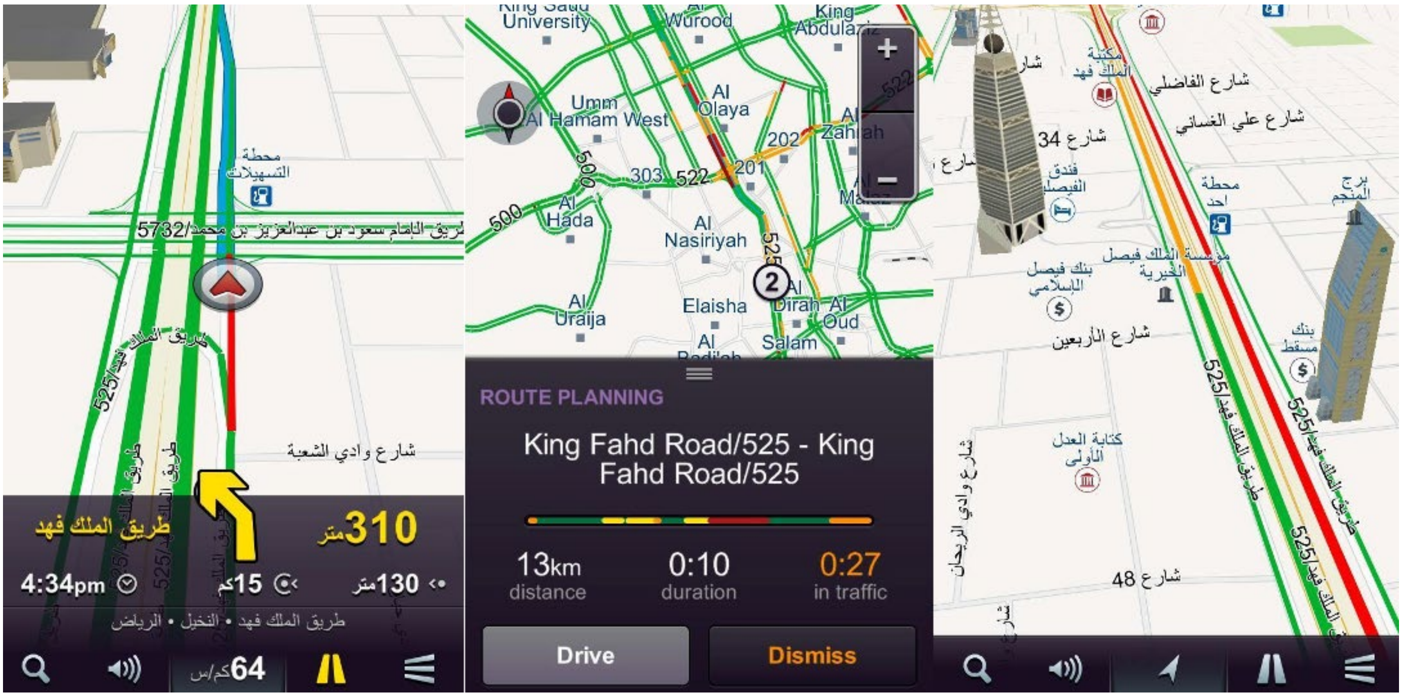
In Dubai, for example, the Road and Transport Authority chose THTC and TomTom to provide critical data to drive their intelligent transport system. This platform uses a visitor management system to alert drivers to accidents and road closures.

In Saudi Arabia, when Riyadh built its new metro, it turned to THTC and TomTom to help manage the impact of the works on road traffic. In this case, TomTom's map and traffic data provide motorists with information on traffic and road closures.[50]

BENEFITS AND OUTCOMES

- Provision of safe and reliable traffic information without delays to motorists, who avoid congested areas, thus reducing transport-related greenhouse gas emissions.
- Safe traffic diversion away from accident-induced blocked lanes.
- Automatic moderation of speed limits during incidents and congestion, thus increasing traffic safety.
- Establishment of a rapid approach to accidents' locations and hospitals during incidents, to provide people with an effective healthcare system.

Figure 10: Delilat Arriyadh navigation app supporting King Abdulaziz's project for public transportation in Riyadh



Credit: Apkpure[51]

50 Kenneth Clay, 'THTC and TomTom Transform Traffic Management in the Middle East,' TomTom, 10 July 2020, www.tomtom.com/blog/traffic-and-travel-information/traffic-management-middle-east/

51 Arriyadh Development Authority, 'Delilat Arriyadh,' https://m.apkpure.com/it/delilat-arriyadh-%D8%AF%D9%84%D9%8A%D9%84%D8%A9-%D8%A7%D9%84%D8%B1%D9%8A%D8%A7%D8%B6/com.mireo.ada

Road and Traffic Management System

GEOGRAPHY
Israel

SUPPLIER
Waycare

USE CASE
Traffic and vehicle monitoring

SATELLITE APPLICATION
GNSS and EO

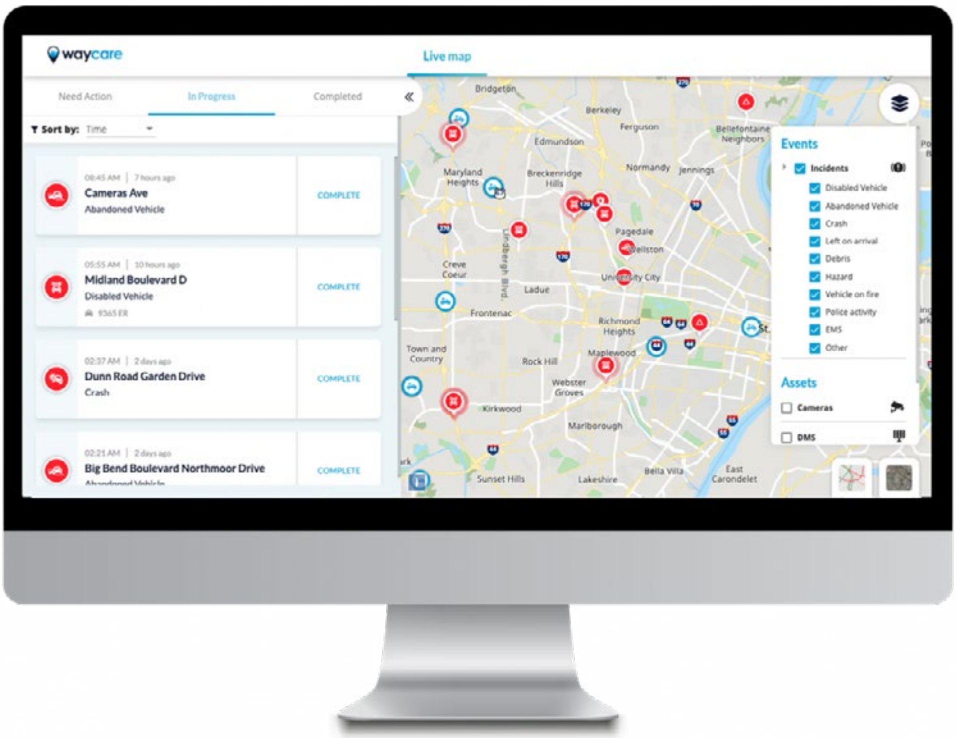
DESCRIPTION

Waycare uses data from transportation agencies' existing infrastructure, data from phone apps like Waze and Google Maps that use GPS, and meteorological data from EO satellites.[52] It provides accurate monitoring of the flow of traffic and congestion management. For example, it looks at where an accident is most likely to happen and provides suggestions for operator intervention. The data provided by moving vehicles is key to making the system work, as apps like Waze can record drivers' speeds, when they brake, and when traffic is blocked, so it is possible to use the same data from GPS to manage transport.[53]

BENEFITS AND OUTCOMES

- Provide accurate and reliable information on travel times to make journeys more efficient and less polluting.
- Control traffic flows to optimise driver speeds and prevent slowdowns that cause congestion and air pollution.
- Analyse causes of congestion so that roads and new infrastructure can be planned in line with urban sustainability.
- Capture marketing and population movement data for businesses.

Figure 11: Waycare's road and traffic management system



Credit: Mic[54]

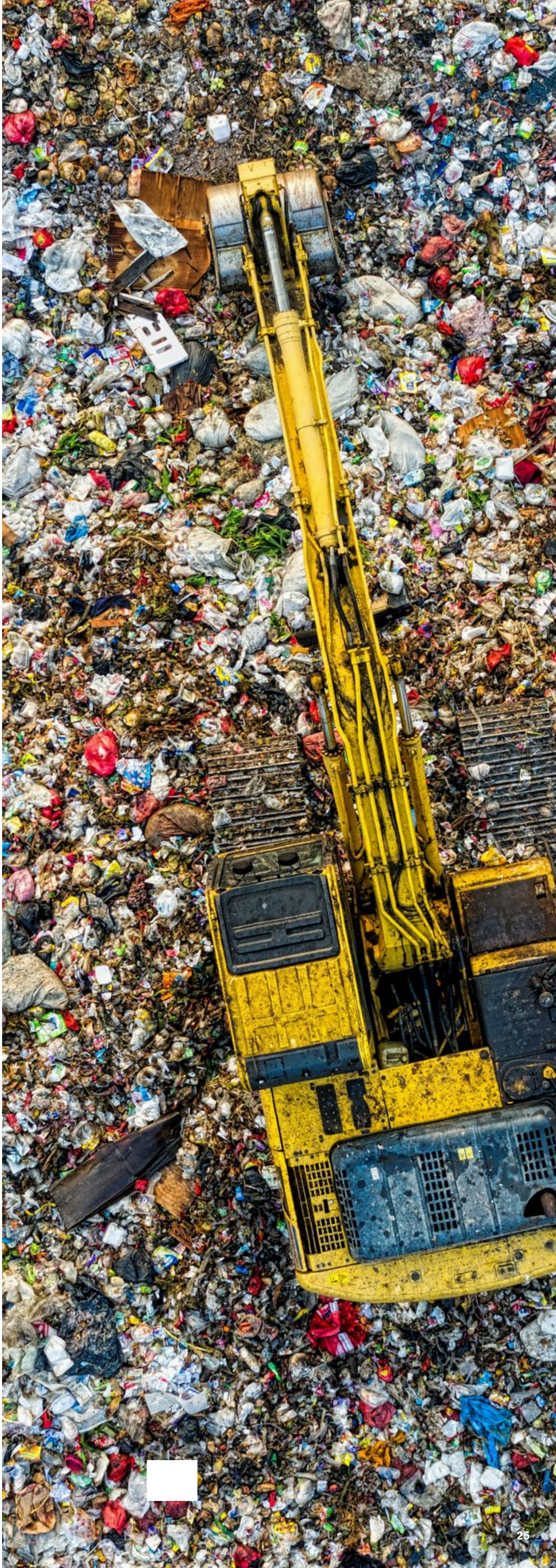
52 Waycare Tech, 'About Us,' https://waycaretech.com/
53 Brian Blum, 'Traffic-monitoring Tech Will Make Cities Smarter and Safer,' Israel 21c, 20 December 2017, www.israel21c.org/traffic-monitoring-tech-will-make-cities-smarter-and-safer/
54 Mashcal, 'Waycare,' MIC, https://mic.org.il/en/solutions/waycare/

Waste

Satellite applications allow for monitoring of waste collection processes, including optimal siting of waste collection points and transport routing. Waste disposal sites, including illegal landfills, can be optimally planned and/or identified. Existing waste disposal sites can be thermally monitored to forecast and provide early warnings of landfill fires. Finally, satellite applications can monitor the vegetation and chemical composition of landfills to assess environmental damage.

Table 5: List of use cases for waste

Use Case	Domain-Specific Examples
Waste collection, transportation, and disposal operations	Route planning for waste collection Site selection exercises for transfer stations, landfills, or waste collection points
Waste disposal sites	Identifying the optimal waste landfill sites Locating and mapping different kinds of waste disposal sites, including illegal landfills
Landfill thermal mapping	Forecasting of fire-prone dumping areas Detection and early warning of landfill subsurface fires
Landfill environmental assessment	Assessing vegetation cover and chemical composition of the surface to monitor landfills' environmental impact



WASTEMON

GEOGRAPHY
Europe and Canada

SUPPLIER
Planetek Italia

USE CASE
Waste disposal sites

SATELLITE APPLICATION
EO

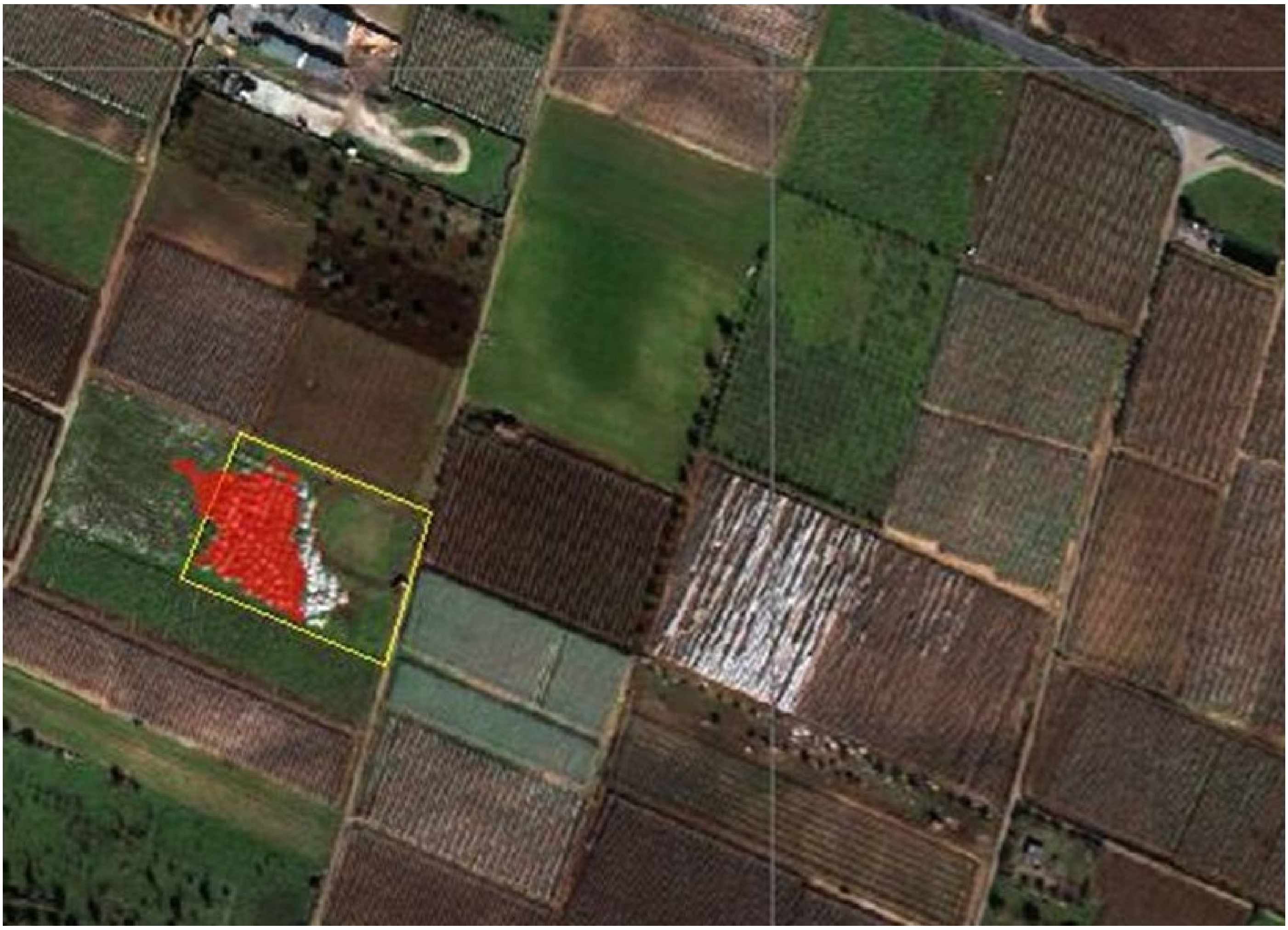
DESCRIPTION

This project implemented by Planetek aims to monitor waste to identify illegal dumps that negatively impact the environment and human health. Thanks to the use of EO satellites, it is possible to map these areas with very high-resolution images. From the satellite images, it is possible to filter out areas with potential buried and surface waste, identifying illegal dumps that are still active.[55]

BENEFITS AND OUTCOMES

- Increasing efficiency in waste management in compliance with EU regulations.
- Support for in-situ investigations for more cost-effective solutions.
- Improving the environment and protecting human health.

Figure 12: Detection of an illegal landfill



Credit: Planetek Italia[56]

55 'Satellite Earth Observation Data Provides Regions with Waste Monitoring Services to Improve Waste Management Practices,' EO Pages, 30 May 2013, https://eopages.eu/company/planetek-italia-srl/success-story/satellite-earth-observation-data-provides-regions-with-waste-monitoring-services-to-improve-waste-management-practices

56 Ibid.

WASTE IAP—Space-based Support Services for Waste Management

GEOGRAPHY
Europe

SUPPLIER
Telespazio Vega UK

USE CASE
Waste disposal sites; waste collection, transportation, and disposal operations

SATELLITE APPLICATION
EO and GNSS

DESCRIPTION

This project is part of the ESA Space Solutions portfolio.[57] It aims to support government authorities to prevent criminals who make substantial profits from illegal waste disposal. The main users will be environmental agencies, regulators, waste companies, and compliance schemes.

Telespazio Vega UK will use EO data to monitor legal landfills and identify illegal landfills, alerting users and attaching evidence of the location and extent of the identified landfill. Change detection routines are applied using a time-series of data to identify potential sites where illegal waste dumping occurs.

GNSS technology will be also used to track the life cycle of waste from collection to disposal by embedding GNSS devices in vehicles transporting waste to inform authorities when a load of waste is directed from its intended destination to an illegal dumping site.[58]

BENEFITS AND OUTCOMES

- Monitoring known legal landfills to ensure that they do not cross dedicated boundaries, thus improving waste collection systems.
- Identifying illegal landfills to close and dismantle the system in compliance with current regulations.
- Monitoring waste disposal from source to destination, thus preventing environmental stress and ecological deficit.

Credit: “Learning to Identify Illegal Landfills through Scene Classification in Aerial Images” (Rocio Nahime Torres and Piero Fraternal)

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57 ESA Space Solutions, ‘Who We Are,’ https://spacesolutions.esa.int/

58 ESA Space Solutions, ‘Waste IAP,’ https://business.esa.int/projects/waste-iap

Monitoring landfill sites in Kuwait

GEOGRAPHY
Kuwait

SUPPLIER
Ryerson University (Canada)

USE CASE
Waste disposal sites; landfill thermal mapping

SATELLITE APPLICATION
EO

DESCRIPTION

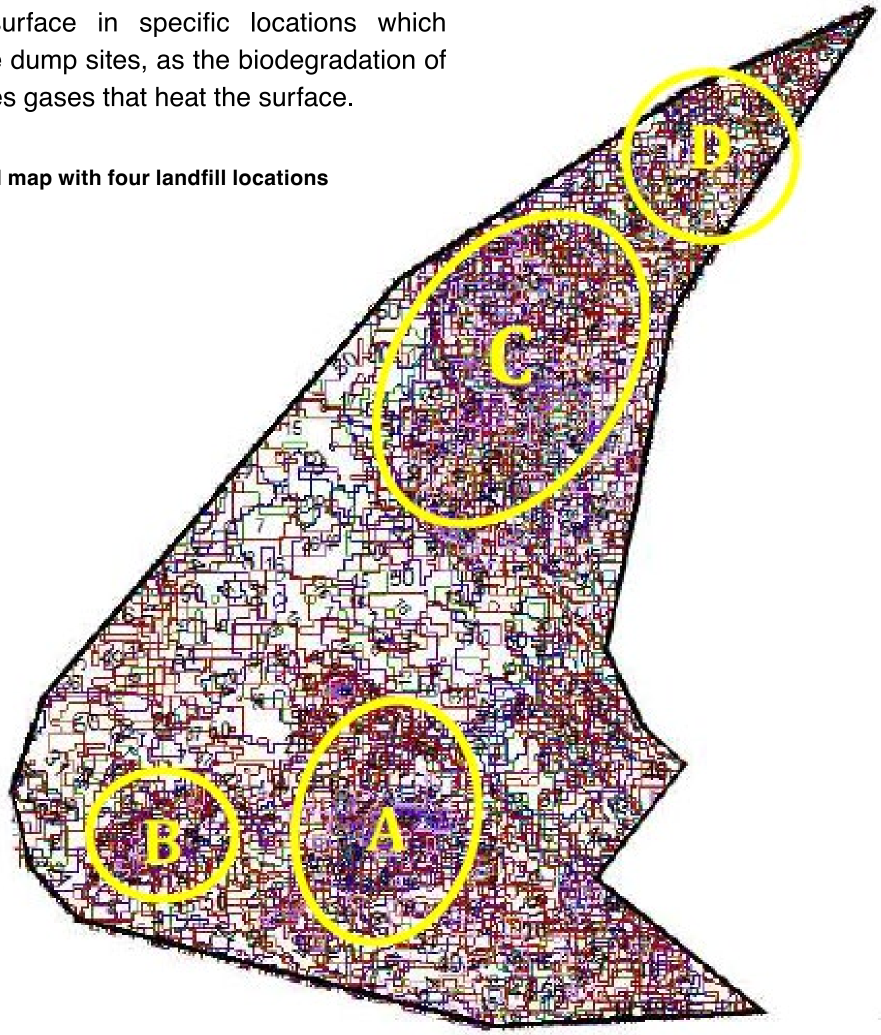
Ryerson University conducted a study in 2010 aiming to identify and monitor landfills in Kuwait and their effect on the environment using satellite sensors. In the early 1980s, people began dumping domestic and industrial waste in a designated area that was not registered by the authorities. However, over the years, residential areas of the country have increased, expanding very close to the illegal dumping site. Therefore, it is important to assess the landfill's environmental and health effects.

The satellite application highlighted higher temperatures of the earth's surface in specific locations which coincided with the dump sites, as the biodegradation of the landfill releases gases that heat the surface.

BENEFITS AND OUTCOMES

- Monitoring unregistered disposal sites to inform the authorities to intervene in compliance with environmental regulations.
- Assessing the health of people living near dumping sites and providing them with appropriate assistance.
- Monitoring gas that can create explosive hazards within a landfill environment, adjacent properties, and residential zones.

Figure 13: Combined map with four landfill locations



Credit: Ryerson University[59]

59 Ahmed Shaker, Kamil Faisal, Nagwa El-Ashmawy, and Wai Yeung Yan, 'Effectiveness of Using Remote Sensing Techniques in Monitoring Landfill Sites Using Multi-temporal Landsat Satellite Data,' Al-Azhar University Engineering Journal 5, no. 1 (2010): 542–51, www.researchgate.net/publication/277021859_Effectiveness_of_using_remote_sensing_techniques_in_monitoring_landfill_sites_using_multi-temporal_Landsat_satellite_data.

Energy, extractives, and industry

Satellite applications support the design, construction, and operation of industrial assets to ensure minimisation of costs and environmental impacts across the asset's lifecycle—including decommissioning. Pollution from industrial assets can be identified and tracked, enabling tracking of emissions (e.g., methane) and supporting clean-up operations (e.g., oil slicks). Satellite applications support the definition, management, and compliance of mining and energy permits. They also aid communication of social, operational, and environmental information to local communities and the visibility and transparency of commodity supply chains.

Table 6: List of use cases for energy, extractives, and industry

Use Case	Domain-Specific Examples
Design, construction, operation of energy/mining/ industry assets	Optimisation of operations to minimise costs and emissions Accurate planning of assets, e.g., identifying pipeline routes in inaccessible areas Reliable remote monitoring of sites Monitor decommissioning of sites to minimise environmental damage
Maximise efficiency of fossil fuel exploration and power generation and distribution	Optimisation of electricity grid efficiency Maximise efficiency of exploration and discovery of fossil fuel reserves to minimise greenhouse gas emissions Maximise efficiency of fossil fuel power generation to minimise greenhouse gas emissions
Detecting air, land, and sea industrial pollution	Detection and forecasting the trajectory of oil slicks Monitoring methane and carbon dioxide emissions from assets, e.g., refineries
Industrial environmental and regulatory compliance	Mine compliance monitoring and support to inspectorates Baseline data for Environmental Impact Assessments (EIA)
Mining cadastres and rights	Supporting authorities to define, manage, and monitor compliance with mining rights
Informing local stakeholders, e.g., rural communities	Effective communication of social, operational, and environmental information to local communities
Commodity supply-chain management, e.g., timber, minerals, fossil fuels	Transparency for supply chains and visibility of source and legality of supply

Renewable Energy Space Analytics Tool (RE-SAT)

GEOGRAPHY
Small Island Developing States (SIDS

SUPPLIER
Institute of Environmental Analytics (IEA)

USE CASE
Design, construction, and operation of energy/ mining/industry assets

SATELLITE APPLICATION
EO

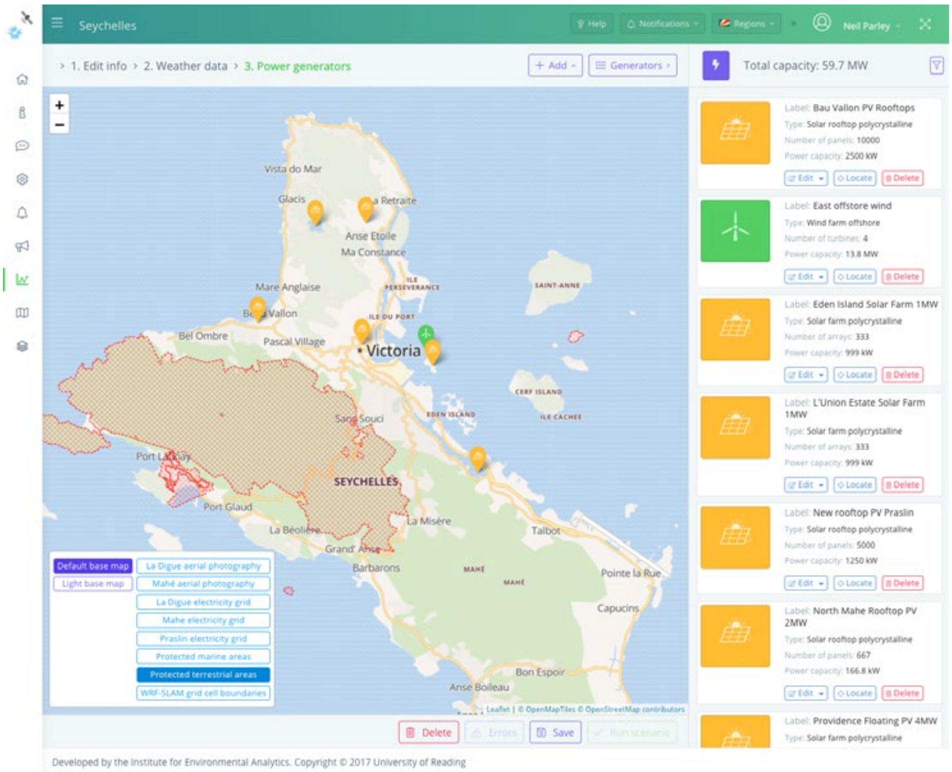
DESCRIPTION

The project, conducted in collaboration with UNDP, aims to identify renewable energy generators through analysis of satellite data. SIDS are heavily dependent on fossil fuels, which has a negative impact on their economy.[60] The platform created by the IEA can help energy planners facilitate the transition to renewable energy. For example, RE-SAT has been used by the Seychelles to try to reach its target of 15% renewable energy generation by 2030.[61]

BENEFITS AND OUTCOMES

- Improvement of renewable energy planning through high-resolution estimates of power availability from renewable sources.
- Optimisation of the positioning of renewable energy infrastructures using GIS.
- Sharing of platform data with all stakeholders, resulting in improved work harmonisation and increased productivity.
- Cost reductions due to savings on natural resource field surveys.

Figure 14: RE-SAT energy planning application showing the location of generators that the user has selected for that particular scenario



Credit: IEA[62]

60 London Economics, Economic Evaluation of the International Partnership Program (IPP): Cost-Effectiveness Analysis, September 2019, www.spacefordevelopment.org/wp-content/uploads/2019/10/UKSA-IPP-Cost-Effectiveness-Analysis-FINAL-for-web-1.pdf

61 Alina Kaiser, 'Renewable Energy Space Analytics Tool (RE-SAT) (Institute for Environmental Analytics) (IPP funded),' Space for Development, 28 June 2019, www.spacefordevelopment.org/catalogue/renewable-energy-space-analytics-tool-re-sat-institute-for-environmental-analytics/

62 Ibid.

Reducing illegal gold mining in the tropical forests

GEOGRAPHY
Ghana and Peru

SUPPLIER
NASA

USE CASE
Industrial environmental and regulatory compliance

SATELLITE APPLICATION
EO

DESCRIPTION

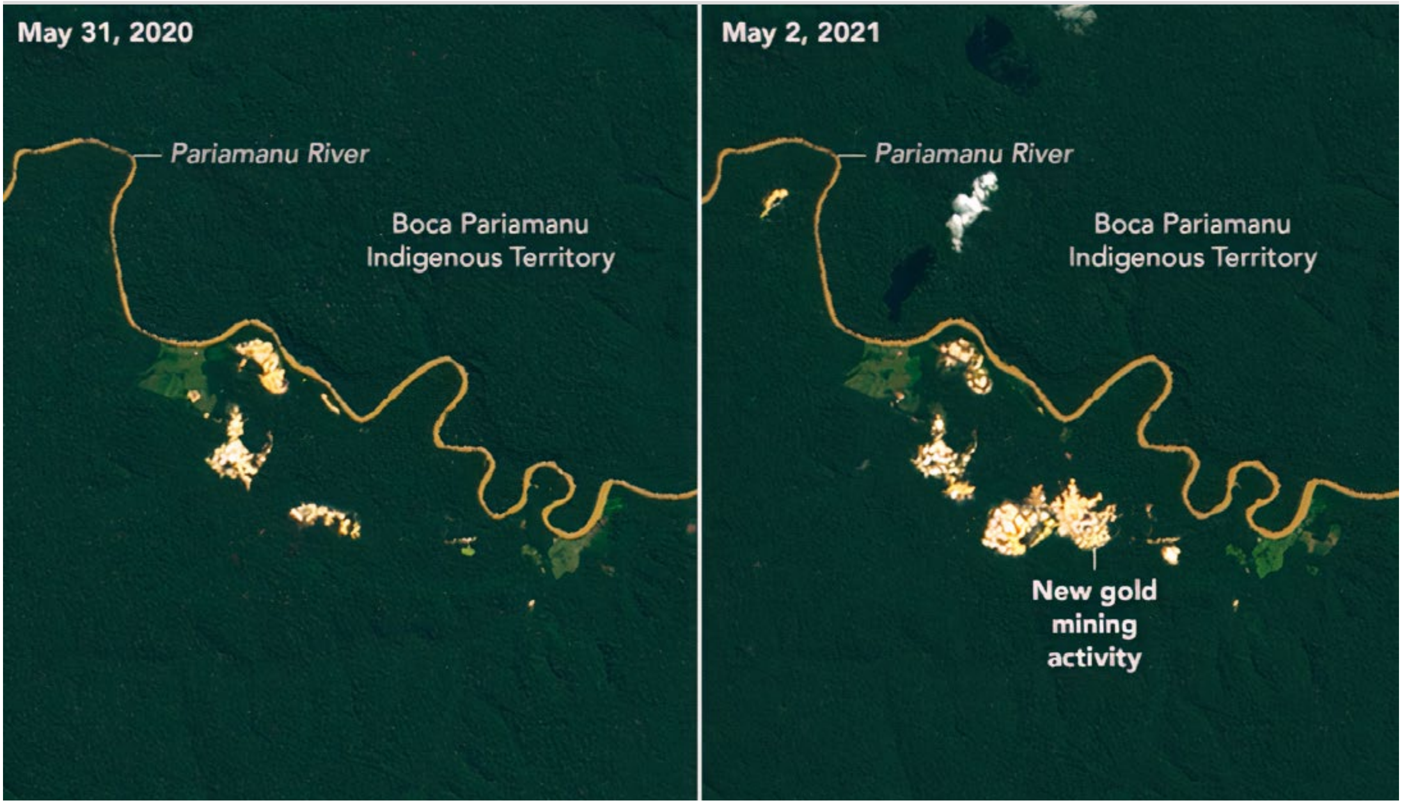
NASA, through the SERVIR-Amazonia and SERVIR-West Africa programmes, is supporting Peru and Ghana in the fight against illegal mining through remote sensing technology. In Peru, gold mining has caused a loss of more than 100,000 hectares of forest over the past 30 years. In Ghana, illegal artisanal mining has affected over 1000 hectares of protected forest reserves as of 2018.

To address these problems, the governments of Peru and Ghana have organised ministerial-level initiatives, the success of which, however, depends on access to real-time information on mining operations. SERVIR uses EO and geospatial technologies to provide that information. SERVIR-Amazonia is developing synthetic-aperture radar (SAR), a monitoring system using radar data that works even when there is cloud cover. SERVIR-West Africa is creating annual composite maps of the footprints of illicit mining areas.[63]

BENEFITS AND OUTCOMES

- Intercepting illegal activities to sanction offenders in compliance with regulations.
- Monitoring degraded mined sites and detecting possible threats to ecosystems.
- Planning land restoration activities.

Figure 15: Images from May 2020 and 2021 show the expansion of gold mining in the Peruvian Amazon



Credit: NASA[64]

63 Sidney Novoa and Foster Mensah, 'Reducing Illegal Gold Mining in the Tropical Forests of Ghana and Peru: A Forthcoming Collaboration across the Atlantic,' SERVIR Global, 10 April 2020, https://servirglobal.net/Global/Articles/Article/2725/reducing-illegal-gold-mining-in-the-tropical-forests-of-ghana-and-peru-a-forthc

64 Aries Keck, 'Teaming Up to Track Illegal Amazon Gold Mines in Peru,' NASA, 16 June 2021, www.nasa.gov/feature/teaming-up-to-track-illegal-amazon-gold-mines-in-peru

Space-D DEWA's Space Programme

GEOGRAPHY
UAE

SUPPLIER
DEWA

USE CASE
Design, construction, and operation of energy/mining/industry assets

SATELLITE APPLICATION
EO and SatComms

DESCRIPTION

The new programme launched by DEWA, Space-D, aims to improve flexibility and agility in monitoring and managing electricity and water networks. The programme will launch into orbit satellites with a sensor that will rapidly assess the impact of climate on energy and water infrastructure and a communications payload to provide backup support for the network.

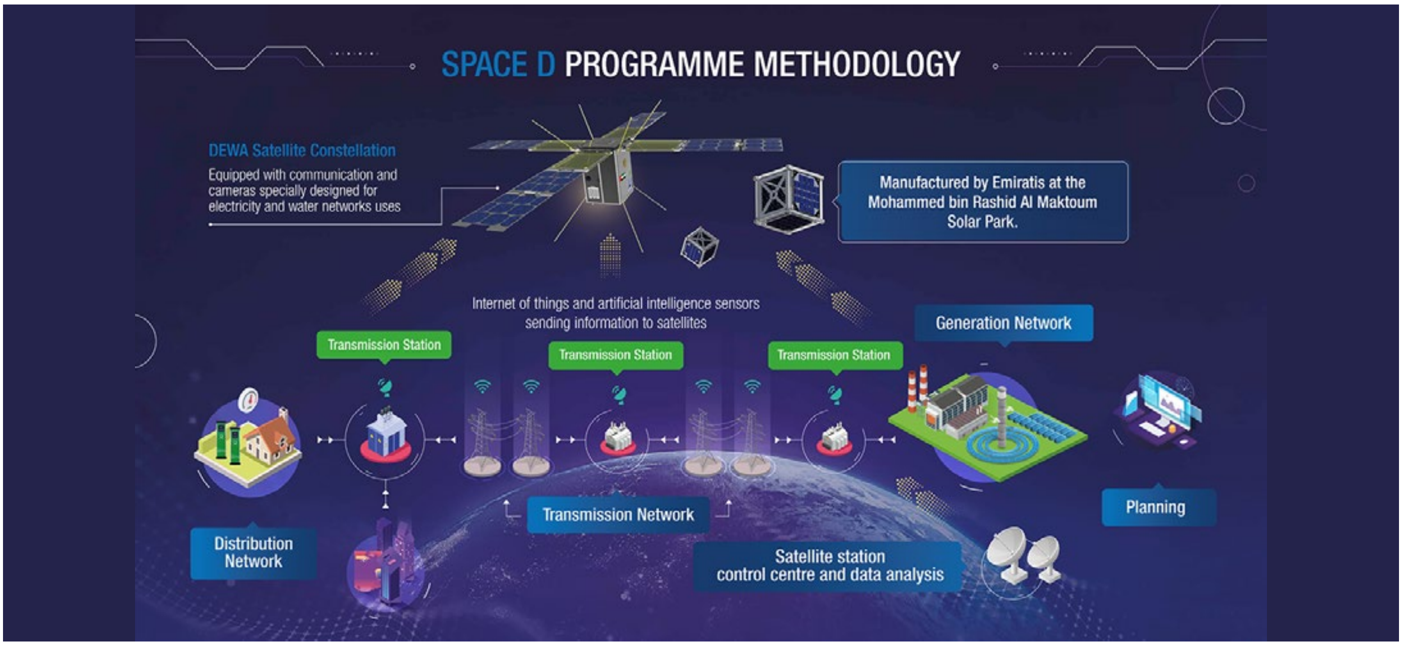
Among other things, the processing of data captured by satellites through AI will enable DEWA to predict when plant maintenance is needed, including real-time detection of events that put the entire system at risk by causing failures. Space-D will also improve solar energy production and management. Data from remote sensing satellites, combined with on-site weather stations and complemented by sky imagers, will allow the development of algorithms and AI models to predict photovoltaic energy production for the next few hours.

The first satellite, DEWA-SAT 1, was launched in January 2022. The imaging nanosatellite will be able to better monitor high-voltage transmission lines, substations, buildings, and solar power stations.

BENEFITS AND OUTCOMES

- Improved efficiency and effectiveness of DEWA and other utility companies' operations planning.
- Improved network reliability and power quality.
- Reduced operating costs and reduced dependence on manual work by automating the monitoring process.
- Improved energy regulation and scheduling, with the ability to predict intermittency risks.
  - Enhanced performance and efficiency of photovoltaic solar panels at the Mohammed bin Rashid Al Maktoum Solar Park.

Figure 16: Space-D programme methodology



Credit: SDG Action[65]

65 SDG Action, 'Space-D: Innovation for the SDGs,' 16 June 2021, https://sdg-action.org/space-d-innovation-for-the-sdgs/

BGAN High Data Rate (HDR)

GEOGRAPHY
Algeria

SUPPLIER
Inmarsat

USE CASE
Design, construction, and operation of energy/mining/industry assets

SATELLITE APPLICATION
SatComms

DESCRIPTION

Like many organisations in the oil and gas industry, Berkine, a joint operating association formed by Algeria's national oil company Sonatrach, sends its exploration teams to remote locations to find potential drilling sites. In these locations terrestrial communication infrastructure is non-existent. This poses a problem for operations, as the teams must send high volumes of data, from test reports to images and videos, to the central site every day.

Inmarsat's BGAN HDR service provided higher bandwidth speeds than previously possible using Very Small Aperture Terminals (VSAT). Along with the service, Inmarsat provided Berkine with ultra-portable EXPLORER terminals, suitable for live broadcast, which allow users to connect their own devices for calls and connectivity.[66]

BENEFITS AND OUTCOMES

- Real-time data transfer from drilling sites to the central site, thus enhancing work efficiency.
- More effective decision-making, with faster evaluation of potential extraction sites.
- Increased safety of operations for remote crews by providing fast health services.
- Reduced exploration costs.

Figure 17: A Berkine worker communicating using Inmarsat's EXPLORER terminal

Credit: Inmarsat[67]

66 Inmarsat, 'Case Study: Berkine,' www.inmarsat.com/en/insights/enterprise/2020/case-study-berkine.htm

67 Inmarsat, 'Connected Oil and Gas: BGAN HDR Case Study,' November 2020, www.inmarsat.com/content/dam/inmarsat/corporate/documents/enterprise/insights/Inmarsat_Enterprise_BGAN_HDR_for_oil_and_gas_case_study_November_2020_EN.pdf.coredownload.inline.pdf

Oil spills from Libya's Derna power and desalination plant

GEOGRAPHY
Libya

SUPPLIER
Conflict and Environmental Observatory (CEOBS)

USE CASE
Detecting land and sea industrial pollution

SATELLITE APPLICATION
EO

DESCRIPTION

In June 2021, three spills, which appear to be oil, occurred at Libya's Derna power and desalination plant. Through the analysis of satellite imagery, CEOBS identified the extent of some of the spills that occurred along the Libyan coast after other media entities had started talking about them.

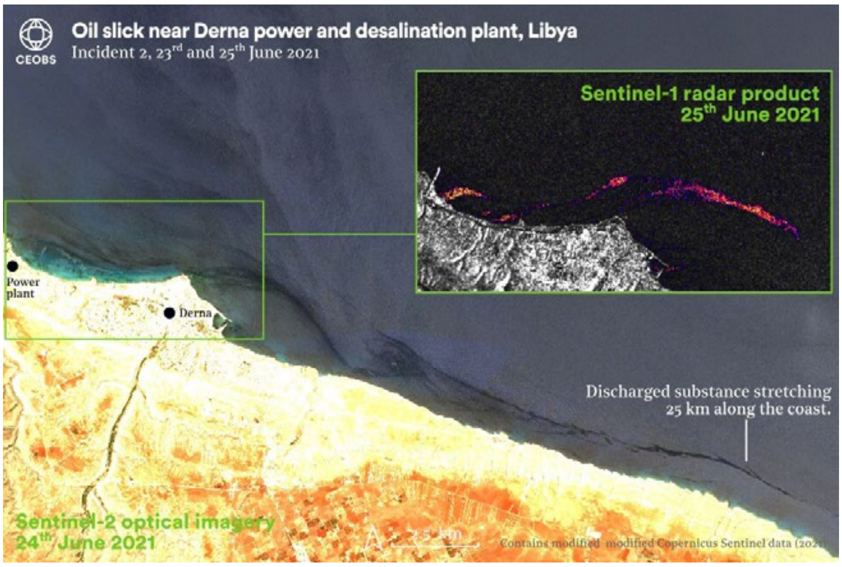
Analysing the EO data archive up to January 2018, CEOBS identified two similar incidents between May and June of that year, during the height of the battle for Derna.[68] In addition, satellite imagery showed that these spills originated from the power plant complex, even though it had been inactive for three years. The images also showed stagnant pollution, leading the Libyan General Environment Authority to believe that the source of the spills is the drainage pipes of the fuel storage tanks, which are flooded with stagnant oily water.

Finally, the historical analysis of EO data carried out by CEOBS revealed numerous other discharges into the sea off the coast of Derna during periods of heavy rainfall, possibly revealing shortcomings in wastewater treatment.[69]

BENEFITS AND OUTCOMES

- Assessment of the extent of the spill and prediction of possible further extensions, improving clean-up efforts.
- Assessment of environmental and health consequences to implement immediate intervention measures.
- Identification of the cause of the spills and targeted action to stop the problem.
- Understanding of the drivers of the problem through analysis of historical data to prevent it from recurring.

Figure 18: Oil slick near Derna power and desalination plant, Libya



Credit: CEOBS, spatial resolution unknown[70]

68 Sami Zaptia, 'UN Concerned by Increasing Humanitarian Crisis in Derna and Calls on All Parties to Respect Human Rights and Conventions,' Libya Herald, 31 May 2018, www.libyaherald.com/2018/05/31/un-concerned-by-increasing-humanitarian-crisis-in-derna-and-calls-on-all-parties-to-respect-human-rights-and-conventions/

69 Eoghan Darbyshire, 'Oil Spills from Libya's Derna Power and Desalination Plant,' Conflict and Environment Observatory, 7 July 2021, https://ceobs.org/oil-spills-from-libyas-derna-power-and-desalination-plant/

70 Ibid.

Monitoring and mapping soil chromium pollution in a mine-waste dump

GEOGRAPHY
Iran

SUPPLIER
University of Birjand (Iran)

USE CASE
Landfill environmental assessment

SATELLITE APPLICATION
EO

DESCRIPTION

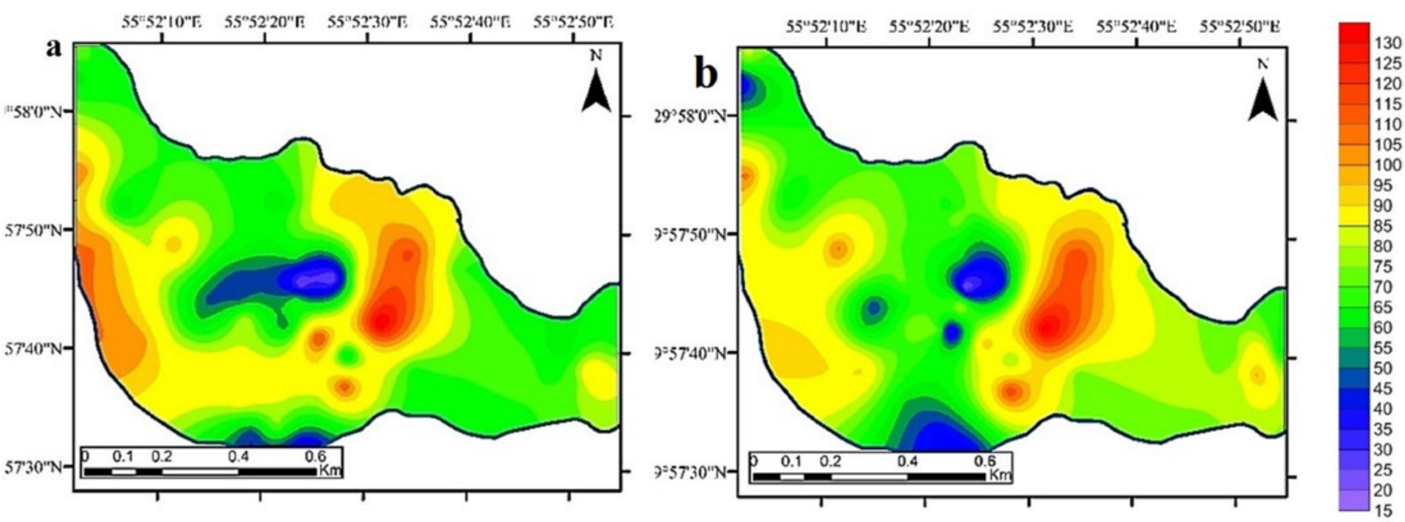
This study aims to demonstrate the ability of satellite sensors to detect chromium in Iran's largest copper mine, Sarcheshmeh. Indeed, mining and related activities are among the most polluting, releasing toxic elements into the environment if not managed by an efficient waste system.

After taking soil samples from one of the dumping sites of the Sarcheshmeh mine, students experimented in the laboratory with the capability of satellite imaging as an alternative to traditional sampling and chemical analysis methods. The study showed that remote-sensing data coupled with special machine learning algorithms can rapidly detect soil pollution.[71]

BENEFITS AND OUTCOMES

- Monitoring potential pollution-related threats to the environment.
- Containment actions by the authority to avoid health or environmental risks.
- Savings of money and time on field analysis by allowing remote access to satellite data.

Figure 19: Spatial distribution maps of chromium measured (a) and predicted by the satellite application (b)



Credit: V. Khosravi et al.[72]

71 Vahid Khosravi, Faramarz D. Ardejani, Asa Gholizadeh, and Mohammadmehdi Saberioon, 'Satellite Imagery for Monitoring and Mapping Soil Chromium Pollution in a Mine Waste Dump,' Remote Sensing 13, no. 7 (2021): 1277, https://doi.org/10.3390/rs13071277

72 Ibid.

Tourism

Satellite applications help balance tourism's economic growth and job creation with the preservation of cultural and natural heritage. They are used to assess and minimise the environmental pressures from tourism. They can provide tourists with near real-time information, e.g., the level of crowds to minimise overcrowding. Satellite applications are also used to identify optimal regions for development of ecotourism.

Table 7: List of use cases for tourism

Use Case	Domain-Specific Examples
Preservation of cultural and natural heritage	Mapping of different cultural and heritage sites providing information to visitors Assessment of needs for maintenance
Minimising tourism's environmental impact	Assessment and minimisation of environmental impact of tourism activities
Assistance to tourists	Providing tourists with the near real-time information, e.g., transportation and level of crowds Ensure tourists' safety Assist tourists with updated maps
Ecotourism[73]	Identifying areas with greater capacity to promote ecotourism

73 Tourism directed towards exotic, often threatened, natural environments intended to support conservation efforts andobserve wildlife.

Mapping potential zones for ecotourism

GEOGRAPHY
Brazil

SUPPLIER
Ecotourism

USE CASE
Federal University of São Carlos (Brazil)

SATELLITE APPLICATION
EO

DESCRIPTION

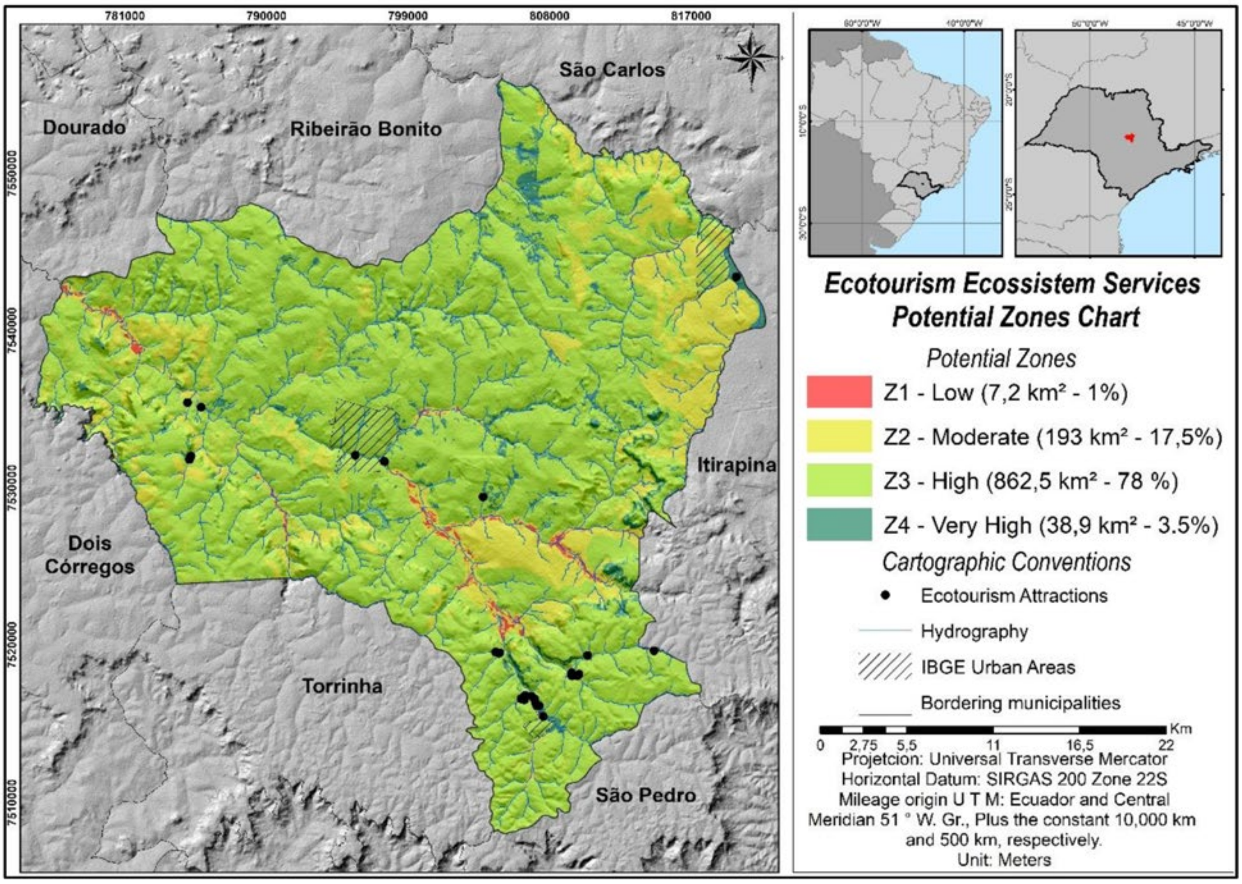
Ecotourism has developed in recent years to reconcile economic development with environmental conservation. Taking the city of Brotas in Brazil as a case study, the Federal University of São Carlos conducted a GIS-based study to identify areas with the greatest capacity to promote ecotourism. The adaptability to become an area for ecotourism comes from the presence of certain features, such as waterfalls, fishing sites, scenic beauty, etc. Less viable areas are those that present greater fragility caused by, for example, periodic floods, fragile soil, and erosion-prone areas.

This study's analysis was based on EO data considering environmental, topographic, and socioeconomic parameters. After processing this data, it was possible to create a chart for the Brotas municipality showing the most suitable areas for ecotourism attractions (Figure 20).

BENEFITS AND OUTCOMES

- Direct contributions to the adaptation of sustainable practises to specific territories.
- Guidance for sustainable territorial management.
- Support for local communities through ecotourism.

Figure 20: Ecotourism ecosystem services potential zones chart



Credit: J.V. Roque Guerrero et al.[74]

74 João V. Roque Guerrero, António A. Teixeira Gomes, José A. de Lollo, and Luiz E. Moschini, 'Mapping Potential Zones for Ecotourism Ecosystem Services as a Tool to Promote Landscape Resilience and Development in a Brazilian Municipality,' Sustainability 12, no. 24 (2020): 10345, https://doi.org/10.3390/su122410345.

Trailze

GEOGRAPHY
Israel

SUPPLIER
Trailze

USE CASE
Assistance to tourists

SATELLITE APPLICATION
GNSS

DESCRIPTION

Trailze is a startup created in 2014 in Israel, which created an app to facilitate navigation for those who practice outdoor activities, such as hiking, biking, and others. Many digital maps are still inaccurate and incomplete.

The Trailze app relies on topographic maps from OpenStreetMap as background information, but is substantially based on crowdsourced data; while out hiking, users can record their itinerary and share it on the app.

BENEFITS AND OUTCOMES

- Navigational assistance to tourists who, thanks to increased safety, will be more attracted to outdoor activities in harmony with nature.

Figure 21: Trailze

Credit: Trailze

Monitoring sensitive cultural heritage sites from space

GEOGRAPHY
Syria

SUPPLIER
German Aerospace Centre (DLR)

USE CASE
Monitoring and evaluation; preservation of cultural and natural heritage

SATELLITE APPLICATION
EO

DESCRIPTION

For this project, the German Archaeological Institute asked DLR to analyse a series of satellite images of Palmyra in Syria, a UNESCO World Heritage Site damaged by the war waged by the Islamic State between 2015 and 2017. Once the necessary satellite images, both pre- and post-war, had been collected, it was possible to analyse the extent of the damage. The data analysts also used automatic image-processing algorithms to streamline the search.[75]

BENEFITS AND OUTCOMES

- Facilitating a detection of damage, which helped the German Archaeological Institute decide on and plan its support for reconstruction works once the site became accessible again.
- Supporting damage monitoring from space, thus overcoming in-situ data collection during war situations.
- Tracing illegal looting of artefacts from the site.

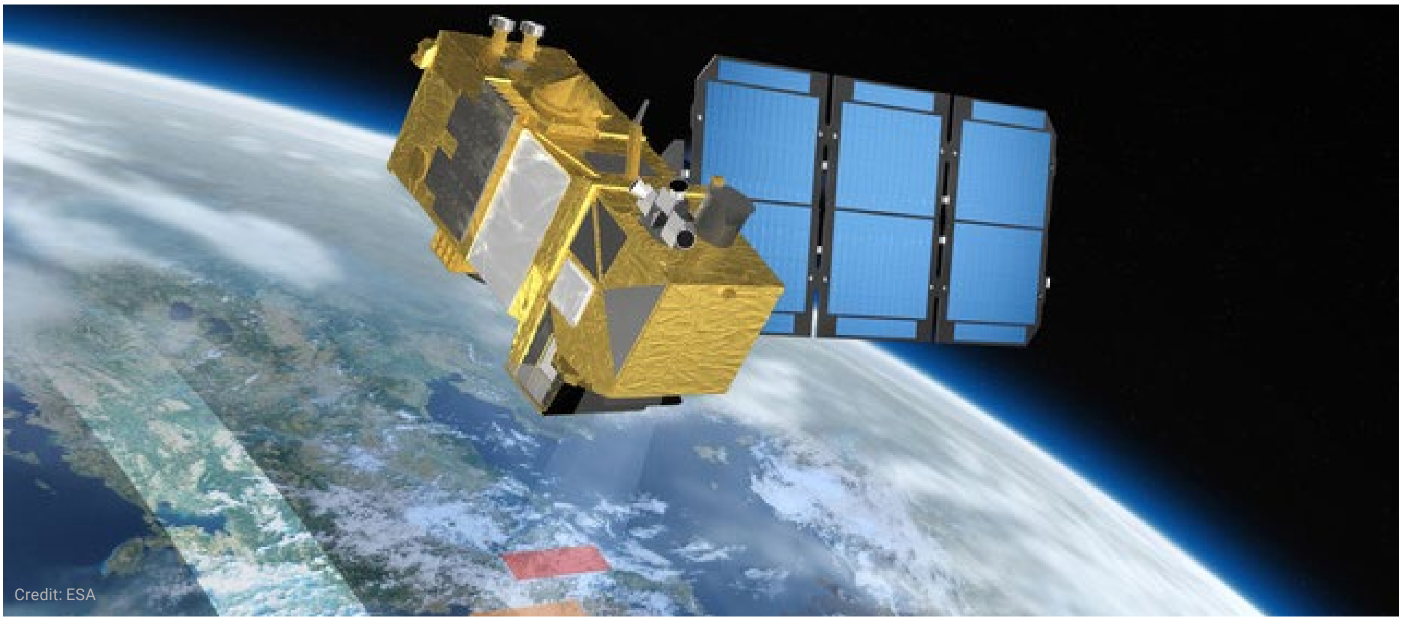
Figure 21: Damage to cultural sites

Credit: Eurisy[76]

75 Eurisy, 'The Case of Palmyra: Monitoring Sensitive Cultural Heritage Sites from Space,' 2019, www.eurisy.eu/stories/the-case-of-palmyra-syria-monitoring-sensitive-cultural-heritage-sites-from-space_264/

76 Ibid.

Barriers to uptake of satellite applications within the green economy



Key points

- There are multiple barriers to the further adoption of satellite applications for the green economy.
- Barriers to supplying satellite applications (supply chain) include:
  - Financial and non-financial resources
  - Data availability
  - Talent
  - Regulatory constraints
  - Piloting and duplication
- Barriers to using satellite applications (demand chain) include:
  - User awareness and resistance (particularly for government ministries/agencies)
  - Lack of evidence of impact
  - Technical expertise and skills
  - IT infrastructure
  - Procurement challenges
  - Green economy aspirations

As shown in previous chapters, the use of satellite technology for the green economy will require public bodies and private sector companies to integrate new types of data into their decision-making processes and investment appraisals. However, in many cases, there are barriers that prevent those organisations from acting unless they can formulate a clear business case with a viable Return on Investment (ROI).

Therefore, the barriers to further adoption of satellite applications to achieve green growth objectives can be divided into two categories:

- Barriers to supplying satellite applications (supply chain)
- Barriers to using satellite applications (demand chain)

Barriers to supplying satellite applications

Financial and non-financial resources

Individual satellite applications, and the supply-chain organisations that produce them, require financing. When these applications—or the core purpose of an organisation—are of value to society (i.e., a public good), there may be a solid rationale to support the provision of public, taxpayer-generated funding via public procurements or third-party grants. Grants tend to be provided by governments and development agencies for a very specific "public good" purpose. This purpose might include academic research, or work to support sustainable development or sustainability efforts. Typically, funding will be requested for short-term projects lasting one to three years, with reporting obligations and Monitoring and Evaluation (M&E) activities attached to encourage full accountability of the grant recipients.

Private companies seeking these grants may go from grant to grant, seeking funds for specific projects to the neglect of longer-term commercialisation prospects or scalability. As a result, organisations reliant on publicly funded grants may have less scope to innovate and to adopt a longer-term perspective, to the detriment of building organisational capacity and expertise. Project funding may also be limited in scope, with insufficient funds for user-needs assessments or for salaries of highly technical staff with in-demand skills.

When supplier organisations are unable to attract (sufficient) public funding to develop their satellite applications, they might look to other forms of capital, including debt and equity investment. Unlike grants, this capital will require repayment or an exchange of equity and can be costly and/or particularly difficult to attract. This type of financing is typically even more difficult to find in developing regions where the existence of "venture" and early-stage capital is limited. In October 2021, the MBRSC launched the "Space Ventures" initiative to support UAE-based startups in the space sector. The initiative is working with incubator and accelerator programmes to support the development of both the upstream and downstream areas of the space sector, including communications, data storage, satellite manufacture, robotics, and space hardware and software development. These initiatives are important for the nascent satellite application sector to find the capital they need to develop and then market their products.

Beyond financing, producing satellite applications requires skills in EO, remote sensing and GIS, software engineering, data science, machine learning, and co-development with domain-specific expertise to ensure relevance and usefulness. All these skills are highly prized, and staff turnover following training programmes is an issue for skills retention.

Data availability

Data availability has been a barrier to satellite application development in some parts of the region. Many countries within MENA have relied on satellite data from other countries, due to a smaller number of MENA-based satellite operators. Until recently, there has been limited availability of sophisticated (e.g., radar) imagery, and cost barriers have prevented more use of commercial data. However, with the recent and upcoming launches of new satellites by countries in the region, it is expected that some of these satellite data challenges will be addressed.

Satellite applications also benefit from other types of data which are used to refine algorithms to improve their relevance and accuracy for users. In some cases, ancillary data requirements may be very significant; there may not be sufficient resources to gather the necessary data or to make it available more widely for use by developers. As a result, application developers may rely on data inputs that are less contextually relevant or may even be dissuaded from pursuing areas of research or technological innovation as a result.

Lastly, governments can be conservative about hosting data outside of the country, for example, on cloud platforms hosted on data centres outside of the country. Governments may also be reluctant to share data with other countries in the region. In some parts of MENA, cloud service uptake is lagging behind other regions of the world, and there is a need for more awareness-raising about general IT infrastructure and capabilities.

Talent

Another supply-side constraint is the availability of people with the skill set, experience, and knowledge to develop satellite applications to meet user requirements.

Producing applications requires skills in EO, remote sensing and GIS, software engineering, data science, machine learning, and awareness of domain-specific issues to ensure relevance and usefulness. All these skills are in demand at a global level and therefore can be priced at a premium. Training programmes can lead to subsequent retention issues, as people with these skills seek out new opportunities to employ their new expertise. Experts have also suggested that in the MENA region there is a tendency to "buy in" capability and applications rather than develop talent and leadership locally.[77]

Regulatory constraints

Regulation and legislation can introduce significant operational and legal barriers for satellite applications. Conversely, an absence of regulation or enforcement is potentially undesirable, for example, unregulated spectrum use leading to radio interference in satellite signals.[78]

There are five UN Committee on the Peaceful Uses of Outer Space (COPUOS) international treaties and five sets of principles that have been ratified by many countries.[79] The United Nations Office for Outer Space Affairs (UNOOSA) records the existence of 29 national space agencies[80] and a collection of 27 countries' space laws.[81]

Many national space laws reference the UN treaties and principles; however, barriers exist in national regulation influenced by multiple policy areas, including defence and security, industrial policy, economic development, ICT and geospatial data, innovation, and international cooperation. A recent example of national law reducing barriers is India's February 2021 geospatial guidelines, which removed the need for licences and approvals for Indian organisations to create and publish geospatial data (with sensitive exceptions).[82] Indian entities are now allowed to access ground stations and augmentation services for more accurate GNSS real-time positioning and other previously restricted public survey datasets.

The UN International Telecommunication Union (ITU) coordinates radio-frequency spectrums, satellite orbits, and technical standards. By agreement and convention of the 193 member states, all satellites require registration with the ITU by national administrations (e.g., a communications regulator or space agency). To enable deconfliction of radio spectrum usage, the ITU reviews frequency assignment notices submitted by administrations for formal coordination procedures or recording in the Master International Frequency Register (MIFR). These processes face considerable evolving challenges, including:

- Increasing impact of radio interference.
- Limited availability of slots for geostationary satellites.
- Inactive, exaggerated, or updated registrations reserving valuable telecoms capacity unnecessarily.[83]
- Increasing collision and debris risk from satellites, constellations, and mega constellations in LEO.
- Political challenges.[84]

There are many standards relevant to the implementation and delivery of satellite applications that address interoperability and common mapping representations, e.g., Open Geospatial Consortium (OGC),[85] EU Infrastructure for Spatial Information in the European Community (INSPIRE),[86] and the UN Committee of Experts on Global Geospatial Information Management (GGIM).[87] The absence of such standards represents a barrier to uptake, transferability, and integration into wider solutions. However, standards can be complex and difficult to implement and may also represent a complexity and cost barrier for user organisations.

Suppliers must also be aware of export controls, which are used by countries *"to protect national security interests and promote foreign policy objectives."*[88] Governments control the export of sensitive equipment, software, and technology for reasons of national security and foreign policy, and these regulations also cover SatComms, GNSS, and EO. The supply

77 'Middle East and North Africa: Space Capabilities and Security Challenges,' 'Space Capabilities in North Africa and the Middle East: National Priorities and Strategic Goals' panel, NATO Southern Hub Study Day, 27 October 2021

78 Jonathan Amos, 'Europe's Smos "Water Mission" Battles Interference,' BBC News, 5 May 2010, http://news.bbc.co.uk/1/hi/sci/tech/8661228.stm

79 UN Committee on the Peaceful Uses of Outer Space, 'Status of International Agreements relating to Activities in Outer Space as of 1 January 2021,' A/AC.105/C.2/2021/CRP.10, 31 May 2021, www.unoosa.org/res/oosadoc/data/documents/2021/aac_105c_22021crp/aac_105c_22021crp_10_0_html/AC105_C2_2021_CRP10E.pdf

80 UN Office for Outer Space Affairs, 'World Space Agencies,' www.unoosa.org/oosa/en/ourwork/space-agencies.html

81 UN Office for Outer Space Affairs, 'National Space Law,' www.unoosa.org/oosa/en/ourwork/spacelaw/nationalspacelaw/index.html

82 Government of India Department of Science & Technology, 'Guidelines for Acquiring and Producing Geospatial Data and Geospatial Data Services including Maps,' 15 February 2021, https://dst.gov.in/sites/default/files/Final%20Approved%20Guidelines%20on%20Geospatial%20Data.pdf

83 Peter B. de Selding, 'Signal Interference Proposal Could Make the ITU a Watchdog with Some Teeth,' Space News, 10 October 2014, https://spacenews.com/42147signal-interference-proposal-could-make-the-itu-a-watchdog-with-some/

84 Elizabeth Hoffman and Kristen Cordell, 'An Obscure UN Agency Guides Digital Communications—Congress Must Endorse US Leadership,' The Hill, 23 July 2021, https://thehill.com/opinion/international/564527-an-obscure-un-agency-guides-digital-communications-congress-must

85 Open Geospatial Consortium, 'About OGC,' www.ogc.org/about

86 Infrastructure for Spatial Information in Europe, 'INSPIRE Data Themes,' INSPIRE Geoportal, https://inspire-geoportal.ec.europa.eu/theme_selection.html?view=qsTheme

87 UN Statistics Division, 'UN-GGIM,' https://ggim.un.org

88 US International Trade Administration, 'US Export Controls,' www.trade.gov/us-export-controls

chain assumes responsibility for compliance. Under the UNOOSA Principles Relating to Remote Sensing of the Earth from Outer Space, there is a requirement that any country that is the subject of remote-sensing imagery has access to *"available analysed information concerning the territory under its jurisdiction."* However, this is difficult to implement universally across borders and with commercial and export controls in place.[89] Furthermore, for every potential customer, suppliers must know the intended use, end-user contact details, and ultimate destination of the data and cannot distribute export-controlled materials to individuals or companies in "embargoed countries."[90] Organisations based in embargoed countries are also restricted from purchasing data from these supply-chain companies due to such government-specific regulations.

Besides specific regulations, many national governments have policies in place to direct spending to domestic businesses. As a result, the countries that spend the most on space programmes are home to the largest suppliers. There is an intentional bias to keeping that spending in-country, and this directly influences other countries' technical capacity to use satellite data.

Piloting and duplication

A well-known barrier to the use of satellite applications is that of piloting and duplication, when projects or products are implemented with a single or small group of users, often in a single country, but do not scale beyond that initial implementation to become more broadly adopted.

Piloting and duplication are driven by multiple reasons. First, members of the supply chain often see the successful implementation of the project as the result or outcome, without planning or aiming for development of a long-term sustainable offering. Second, funders—be they Government or Development Agency—often provide project-based funding, and their recipients therefore move from one grant-based project to the next. Third, lack of awareness of already-existing satellite applications can lead to duplication.

However, some piloting and duplication is natural and desirable in the nascent stages of a sector. It allows for experimentation and competition before a sector matures and consolidates on a limited number of dominant applications.

Barriers to using satellite applications

User awareness and resistance (particularly for government ministries/agencies)

Across government agencies and industry, there are individuals and even some organisations that champion technological innovations and explore new ways of using data for decision-making. These individuals may engage in pilot initiatives that use satellite applications and seek buy-in and approval for wider involvement. However, across the user community, there is significant variation in the level of awareness of satellite applications, use cases, and advantages over terrestrial data sources. In the MENA region, awareness of satellite applications is reasonably low, with many stakeholders seeing the use of this technology as a "luxury" due to a misunderstanding of its applicability and accessibility to a wide range of stakeholders.[91] This could be due in part to the lack of coverage of satellite applications in curricula throughout the education system. In addition to low levels of awareness, the space sector may encounter issues relating to user trust due to the lack of familiarity with satellite technology and the perception that the industry is closely aligned with defence and intelligence sectors. These perceived security issues in supplier-customer relations are particularly acute in some regions and can stifle the realisation of commercial opportunities.

Cost structures for satellite applications can be unfamiliar and confusing (see section Procurement challenges). Supply-chain players are often unknown to members of government institutions or industry players, and technical capabilities and language are poorly understood. As a result, potential users of satellite applications are unaware of the "art of the possible" to appropriately articulate the user requirements that need to be met. The result of this may be that satellite applications are never fully explored as an option for the green economy community, or that inappropriate or over-specified technical solutions are developed, which are then not valued by their users.

89 UN Office for Outer Space Affairs, 'Resolution 41/65 Principles relating to Remote Sensing of the Earth from Outer Space, Principle XII, www.unoosa.org/oosa/en/ourwork/spacelaw/principles/remote-sensing-principles.html

90 Maxar, 'Maxar Trade Compliance Policy,' 2021, https://maxar-marketing.s3.amazonaws.com/files/legal/201112%20Maxar%20Trade%20Compliance%20Policy%20-%20final%20EXTERNAL.pdf

91 Advisory board member comment.

Lack of evidence of impact

M&E is an objective process of understanding how a project was implemented, what effects it had, for whom, how, and why.

In the satellite applications sector broadly there is a lack of quality M&E and a weak evidence base on the development outcomes and impacts of using satellite applications. Traditionally, supply-chain organisations have been focused on measuring and communicating the scientific and technical achievements of their products, for example, the accuracy of an EO algorithm, as opposed to quantifying the benefits for the demand-chain users, for example, in terms of carbon emission reductions realised or "green" jobs created.

Governments and industry need to understand if and how satellite data can improve or add value to their decision-making as well as the specific circumstances in which that satellite data is particularly cost effective. Many users want to have access to something that is already "proven" and will not be interested until the application has been tested. In many cases, the ROI thesis is not well documented or understood.

Satellite applications can directly support the M&E process. This includes *"Geospatial Impact Evaluations (GIEs) that rigorously evaluate the impacts and cost-effectiveness of specific development interventions and large investment portfolios with spatial data. GIEs methods leverage readily available data, like satellite observations or household surveys, to establish a reliable counterfactual for measuring impacts — at a fraction of the time and cost of a 'traditional' randomized controlled trial (RCT)."*[92] However, such techniques and impact evaluations are currently rare.

Technical expertise and skills

Specific skills are required to both use and produce satellite applications. Usage of applications requires skills in model development, operating the application, data interpretation, combining with other datasets, integrating machine learning approaches, and linking outputs to existing workflows.

A lack of technical competence can also result in a lack of trust in satellite applications. The issue of trust is often compounded by the "Black Box Problem," with machine learning derived applications whereby *"a black box is a system which can be viewed in terms of its inputs and outputs, without any knowledge of its internal workings."*[93] There are some efforts tackling these transparency and replicability issues: sharing guidance on metadata standards, advocating for open source licensing, adopting frameworks based on international human rights law and ethics, and more.

IT infrastructure

Infrastructure is required to use and/or produce satellite applications. This includes access to local or cloud-based processing and storage platforms, and internet access to EO data and the outputs of executed algorithms.

Cloud platforms, such as GCP, AWS, and Microsoft Azure, address these challenges by storing and processing large EO datasets in the cloud, rather than on local IT infrastructure. They are significantly more cost effective and have enabled large processing that was previously not possible without sophisticated computing clusters. However, these platforms require subscriptions and robust internet connections to retrieve results. Google Earth Engine (GEE) is a cloud platform that uses GCP, providing free access for users to conduct analyses that would otherwise require enormous resources to access (download), store, and analyse. This data and GEE's cloud computing capabilities are available to scientists, researchers, and developers, lowering the cost and time of obtaining, pre-processing, and developing products from satellite imagery and building use-case specific applications that ease data analysis and visualisation.

"Vendor lock-in" can be an issue, whereby supply-chain organisations build their initial EO applications on a specific cloud platform and then face issues with switching to other providers later. For example, workflows built on AWS might not necessarily run on GCP.

Whilst cloud platforms reduce storage and processing requirements, they still require a robust internet connection to access outputs. Internet access in developing regions is a well-documented issue, so it is not a major focus of this report. Barriers to internet access include lack of mobile coverage, low access to smartphones or desktop computers, government taxes raising prices on bandwidth, and many more.[94]

92 AIDDATA, 'Geospatial Impact Evaluations,' www.aiddata.org/gie

93 Wikipedia, 'Black Box,' https://en.wikipedia.org/wiki/Black_box

94 Alliance for Affordable Internet, 'A4AI Policy and Regulatory Good Practices,' https://a4ai.org/good-practices/; Melle Tiel Groenestege et al., Accelerating Mobile Internet Adoption: Policy Considerations to Bridge the Digital Divide in Low- and Middle-income Countries, GSMA, May 2021, www.gsma.com/mobilefordevelopment/wp-content/uploads/2021/05/Accelerating-Mobile-Internet-Adoption-Policy-Considerations.pdf

Procurement challenges

Procurement processes are ultimately the connecting and contractual link between the supply chain and demand chain, and there are many challenges within them.

Being an intelligent customer is *"the capability of the organisation to have a clear understanding and knowledge of the product or service being supplied."* [95] It requires the user to be able to discern among the array of satellite applications that the supply chain offers—and what meets the user's requirements and budget. This includes understanding cost ranges and variables such as geographic coverage, data formatting, spatial resolution, IT infrastructure costs like cloud computing, intended use, duration of access, ability to commit to multi-year agreements, and licensing terms like derivative rights (the ability to create data or analytics from satellite imagery or ability to publish).

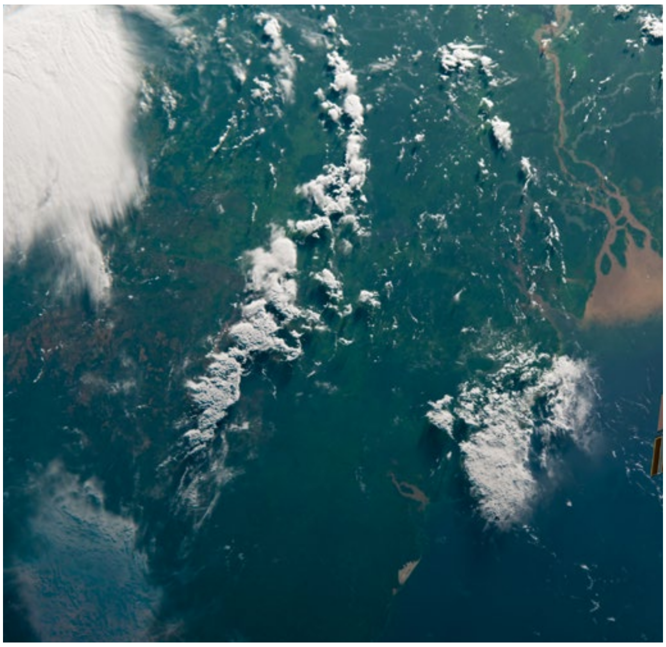
While many across the supply chain freely share technical specifications and demonstrations, they rarely publish pricing. To understand which applications are fit-for-purpose but also affordable, the demand side needs to engage with each provider and/or manage a time- and resource-intensive Request-for-Proposals process. Also, understanding the supply chain's licensing terms requires procurement and legal teams that might not be available in house, who are knowledgeable on these topics.[96]

There are some examples of stakeholders purchasing data layers and making them openly available for philanthropic purposes. For example, the Norwegian Government's International Climate and Forests Initiative (NICFI) is sponsoring universal access to high-resolution satellite monitoring of the tropical forests.[97] NICFI has awarded a US$44 million (£33 million) contract to EO specialists Airbus, Planet, and Kongsberg Satellite Services (KSAT). Andreas Dahl-Jørgensen, Managing Director of NICFI, said, *"the offered licensing terms are particularly good in this bid. It allows everyone to access high-resolution satellite data, without restrictions on use and distribution."* [98]

Green economy aspirations

Although there may be several potential use cases for satellite applications, supply-chain stakeholders may be reluctant to develop applications unless there is a clear longer-term demand from the user community. Demand for satellite applications relating to the green economy may result from both "push" and "pull" factors. So-called "push" factors may include regulatory environments that drive more sustainable operations and seek to enforce industry compliance with regulations and laws that aim to reduce carbon emissions. Conversely, "pull" factors are likely to include potential longer-term cost savings from more efficient productions or investments into green energy.

Although there are many champions for the sustainability agenda across international organisations, national governments, and the private sector, there are potential vested interests that may inhibit these stakeholders from using satellite applications to achieve these positive green outcomes. If this demand is not evident, and the underlying requirements from the user community are unclear, supply-side actors are less likely to pursue these opportunities.



95 Health and Safety Executive, 'Human Factors: Intelligent Customer Capability,' www.hse.gov.uk/humanfactors/topics/customers.htm

96 Caribou Space, 'Beyond Borders. Community Engagement Workshop 2,' October 2021

97 Tara O'Shea, 'Universal Access to Satellite Monitoring Paves The Way To Protect The World's Tropical Forests,' Planet, 2 March 2021, www.planet.com/pulse/universal-access-to-satellite-monitoring-paves-the-way-to-protect-the-worlds-tropical-forests/

98 Norway International Climate and Forest Initiative, 'New Satellite Images to Allow Anyone, Anywhere to Monitor Tropical Deforestation,' 23 September 2020, www.nicfi.no/current/new-satellite-images-to-allow-anyone-anywhere-to-monitor-tropical-deforestation/

Opportunity areas for future intervention

Key points

- Several interventions could be planned to address the barriers outlined above
- These interventions could involve—and benefit—key stakeholder groups such as climate change organisations, the private sector, government bodies, and academia
- Recommended activities to generate the maximum potential for the sector in MENA address four issues:
  - Raising awareness of use cases for satellite technology
  - Building technical expertise and capacity
  - Developing new satellite applications
  - Demonstrating the viability of satellite applications with key user groups

When considering opportunities to address the barriers presented above, it is valuable to consider the various stakeholder groups that could be targeted by possible future interventions.

This section focuses on interventions that could be piloted within the MENA region and which align with the specific barriers identified within the region.

These interventions target four main groups. These groups could be both important initiators of future interventions and key beneficiaries.

- **Climate change organisations:** Both national and international organisations (governmental or nongovernmental) focus on addressing the climate crisis within the MENA region. Satellite applications can be an important information source for these organisations, guiding their policy agendas and shaping their programmatic investments. Climate change organisations therefore represent an important potential user group for new and existing satellite applications. They may use data offered by satellite technologies to forge new partnerships and agreements with government and private sector players and are therefore an important stakeholder for any future intervention.
- **Private sector:** Private enterprise channels investment into key industries, generating local employment and offering products and services within the MENA region. As these organisations pursue green economic growth, they could benefit from the use of satellite applications to ensure compliance with new regulatory and Environmental, Social, and Governance (ESG) requirements. The private sector will also include many of the downstream application developers and service providers that will bring satellite applications to the market. The size and characteristics of this

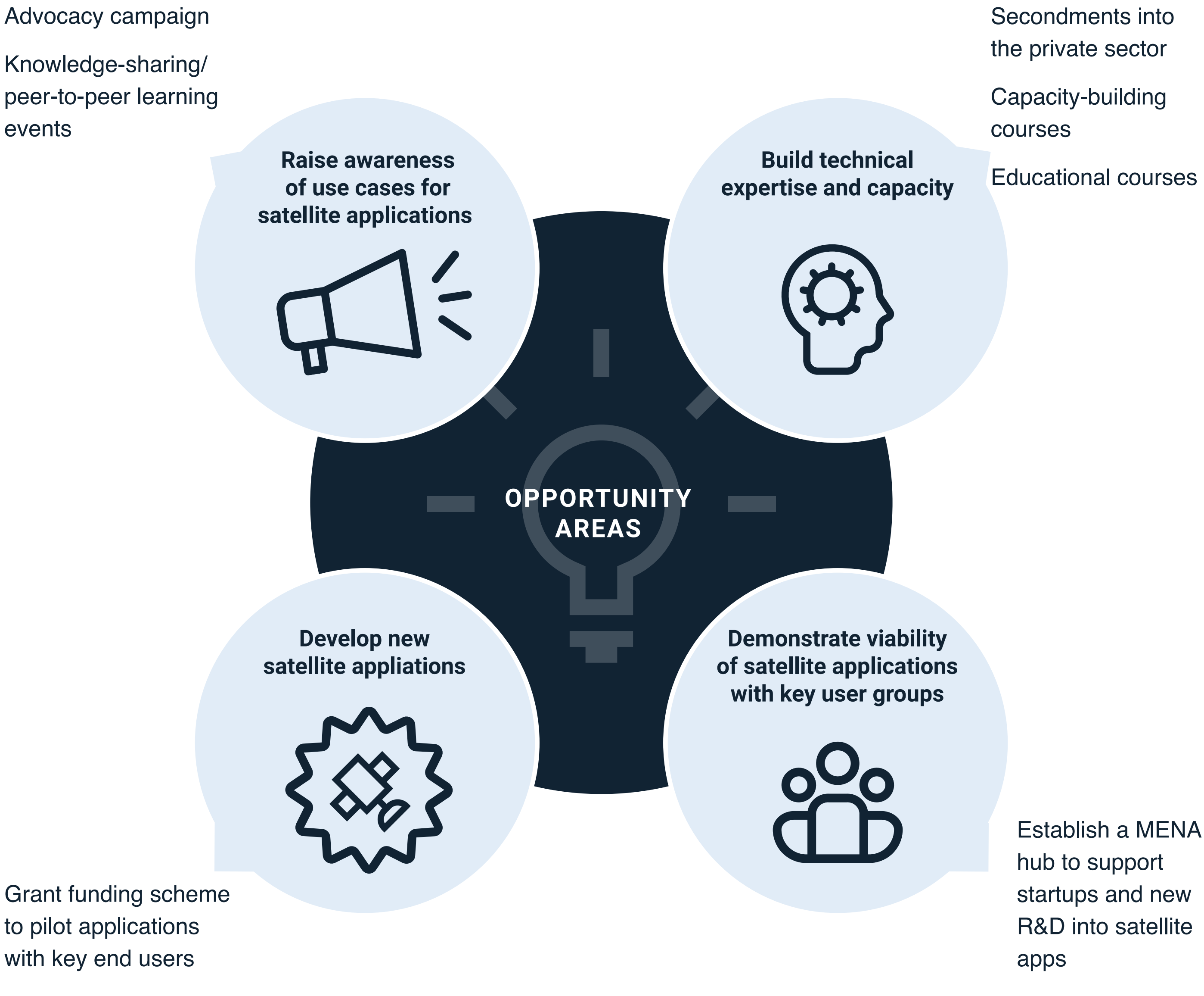
market at the local level will be determined by the actions taken now to promote this innovative activity within the MENA context.

- **Public Sector:** Government agencies and municipalities are responsible for public investment and public services in cities and regions within the MENA region. These institutions are important potential users of satellite applications and therefore should also be included in—and could be beneficiaries of—potential interventions. The public sector can play a leadership role by promoting the use of satellite technologies across their agencies and by investing public funds into the sector to demonstrate its recognition of its importance.

- **Academia:** Educational institutions including those offering vocational training, further education, and skills development within the MENA region can play an important role in developing the skills and expertise needed within the sector and in supporting further research and innovation in new areas.

This report explores four Opportunity Areas that could address the barriers outlined above. For each one, there are a range of intervention ideas, each requiring different resources, partnerships, and time commitments, and generating different types of outcomes and impact. A selection of these ideas is detailed in the tables below.

Figure 22: Opportunity areas for future interventions



The following sections offer several specific intervention ideas for each of the four Opportunity Areas shown in the diagram above. Each intervention is expanded on in the following structure:

- High-level description
- Benefits (including financial, social, and environmental impact)
- Recommended actions (partnerships, time commitment, resources)

Raise awareness of use cases for satellite applications

	Description	Benefits	Recommended actions
Advocacy campaign	Commission a selection of case studies and related knowledge products from the report to be amplified with key audiences through various communications channels.	Help to build awareness of and demand for satellite applications from key actors within the green economy landscape (government ministries, NGOs, international organisations, etc). Generate future commercial opportunities for the space sector by building demand.	Stakeholder engagement plan for targeted advocacy work. Organise key communications products and channel strategy for reaching the main audiences
Knowledge sharing/ peer-to-peer learning events	Run a series of in-person and/ or virtual events to enable existing and potential users of satellite applications to share experiences.	Document experiences and lessons learned to offer guidance to newcomers to the sector. Gather evidence of impact from past users of satellite applications.	Curated community of stakeholders for knowledge sharing. Communications/ events partners to facilitate events.

Build technical expertise and capacity

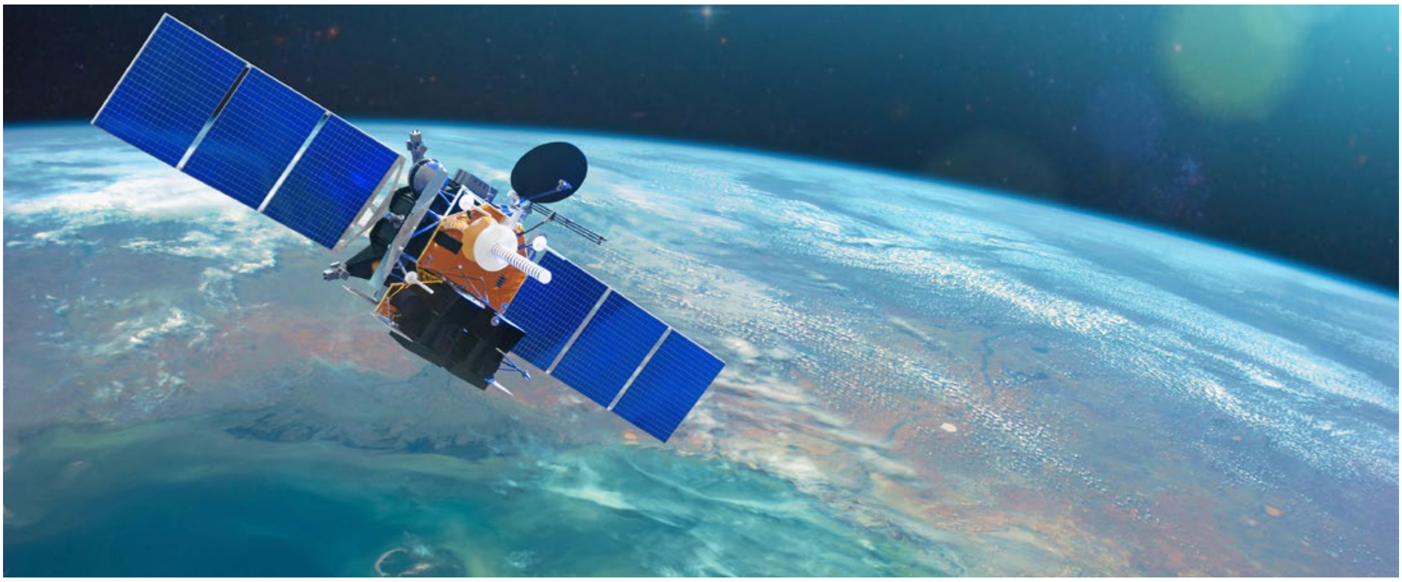
	Description	Benefits	Recommended actions
Secondments from the space sector into the private sector or government organisations	Support technical experts from the space sector to spend time in 'user' organisations within the private or government sectors to improve mutual understanding of requirements/capabilities and knowledge exchange.	Increase in relevance of satellite applications thanks to improved understanding of user requirements. Improved technical understanding of satellite applications' functionality within user organisations.	Engagement and interest from space companies and host organisations to support a secondment.
Capacity-building courses (for professionals)	Develop new or follow existing capacity-building courses to encourage the use of satellite applications for specific use cases and to integrate applications into existing workflows.	Improved technical capacity within user organisations.	Partnerships with existing training providers (e.g., UNOSAT). Buy-in from host organisations.
Educational courses (for students)	Invest in building the next generation of space services companies by developing local talent and building skills such as data science, AI, and programming.	Establishing MENA or specific countries within the region as centres of excellence for satellite applications. Building a thriving space sector that generates economic growth and creates jobs.	Partnerships with local universities and higher education establishments.

Demonstrate viability of satellite applications with key user groups

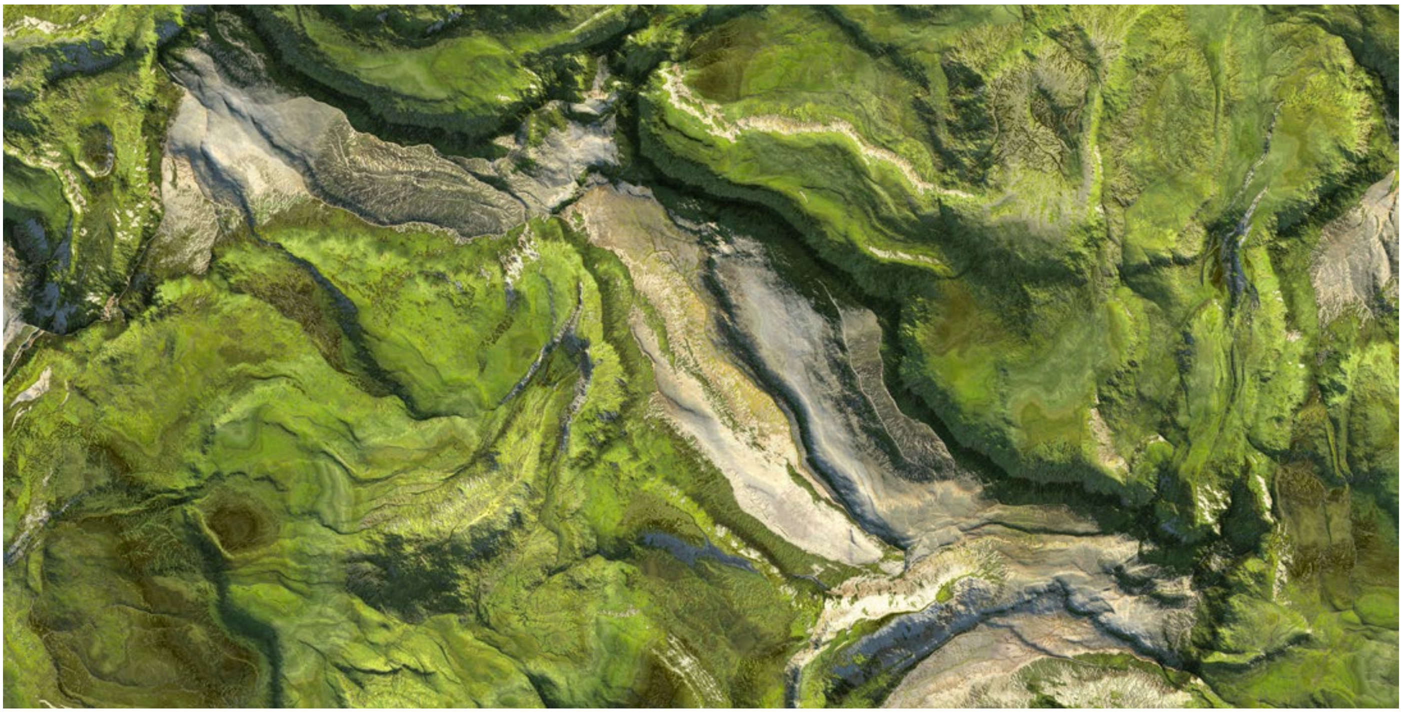
	Description	Benefits	Recommended actions
Establish a MENA hub to support start-ups and new R&D into satellite applications	Create an 'innovation space' for data scientists, developers, and others to work together to develop new applications and companies. This space would offer access to required IT infrastructure, and could also offer subsidised access to satellite imagery and would promote knowledge sharing and co-creation.	Stimulate technological innovation and startup enterprise. Generate employment opportunities.	Partnerships with existing innovation 'spaces' and/or other potential host institutions (e.g., universities). Funding for subsidised facilities, such as IT infrastructure, imagery, and office space

Develop new satellite applications

	Description	Benefits	Recommended actions
Grant funding scheme to pilot applications with end users	Establish a new grant-funding mechanism to support companies to develop and operationalise satellite applications in partnership with end users.	Potential for social and/or environmental impacts thanks to the operationalisation of the application. Future follow-on commercial opportunities for grantees. Improved evidence base from real-world implementations.	Funding for a small number of grants to pilot the applications.



Conclusion



Key points

- Satellite applications could have an important role to play in informing "green" decision-making and investment.
- Interventions are needed within both the supply chain and demand chain of the industry to accelerate uptake and impact of these technologies.

Summary of report's objectives

The objectives of this report were threefold:

1. **To clarify the landscape of satellite applications for the green economy.**
2. **To provide material that catalyses stakeholder collaboration.**
3. **To identify and evaluate opportunity areas for future interventions.**

The report acknowledges that in the MENA region, as in many other parts of the world, a key barrier to increased uptake of satellite applications is a lack of awareness about the potential uses for these applications and the availability of examples of how applications have been used to generate positive impacts. The inclusion of case study examples spanning five different use-case areas serves to inform the reader of the technical capabilities of this technology as employed in some real-world situations across the region and beyond. It is hoped that the potential highlighted by these examples, accompanied by a clear articulation of the various challenges and barriers faced in operationalising satellite applications, might inspire organisations and leaders across the region to identify interventions that can be made to address some of the issues and realise the significant opportunity afforded by these technologies.

Conclusions

As many countries and organisations set about pursuing green economic growth strategies, satellite applications could have an important role to play in informing "green" decision-making and investment. Recent advances in technological capability and processing power, coupled with regional investment into the satellite industry, suggest that we may be on the crest of a wave of innovation that could also create new economic opportunities and jobs in the region. As this report shows, greater uptake of satellite technologies for these purposes will be driven by actions taken within both the supply chain and the demand chain of this sector. There is a need for continued innovation to develop applications that meet the needs of local communities, government departments, and civil society organisations in cost-effective and impactful ways. Similarly, it will be important to generate demand for and interest in these technologies within a wide range of potential user groups so that the use of satellites can become "mainstreamed" even within non-technical professions.

Annex 1 Methodology

General methodology

The team used desk research to identify examples of satellite applications for a green economy. Information was collected from sources including academic papers, grey literature, organisational websites, etc. External input and review were gathered at multiple stages, including:

- **Semi-structured Interviews** – with organisations that represent a spectrum of supply-chain and demand-chain stakeholders (see Acknowledgements).
- **Stakeholder Workshop and Survey** – one virtual workshop with a follow-up survey held with ~10 participants from MENA countries to gain their experiences and challenges with using satellite applications for a green economy.
- **Advisory Group** – calls and report reviews were held with Advisory Group members to gain feedback on findings and conclusions (see Acknowledgements).

Methodology limitations

- Desk research searching was conducted with English keywords, which may limit visibility of applications in Arabic or French.
- The case studies included are a representative sample of satellite applications across the range of green economy domains in the report, not a comprehensive list of all those available.
- This report represents a "snapshot" of satellite applications developed in the recent past, in response to green economy issues in that period. Therefore, information is likely to become outdated with time.

Annex 2
Glossary

AI – Artificial Intelligence

ADB – Asian Development Bank

AWS – Amazon Web Services

COPUOS – United Nations Committee on the Peaceful Uses of Outer Space

EO – Earth Observation

EO4SD – Earth Observation for Sustainable Development

ESA – European Space Agency

EU – European Union

GCP – Google Cloud Platform

GDP – Gross Domestic Product

GEE – Google Earth Engine

GIE – Geospatial Impact Evaluations

GIS – Geographic Information Systems

GNSS – Global Navigation Satellite System

GPS – Global Positioning System

ITU – International Telecommunication Union

M&E – Monitoring and Evaluation

MENA – Middle East North Africa

NASA – National Aeronautics and Space Administration (United States)

NGO – Non-Governmental Organisation

OECD – Organisation for Economic Co-operation and Development

RCT – Randomised Controlled Trial

RCC – Regional Collaboration Centre

RIEIOs – Regional Intergovernmental Economic Integration Organisations

ROI – Return on Investment

SAR – Synthetic-Aperture Radar

SatComms – Satellite Communications

SIDS – Small Island Developing States

UAE – United Arab Emirates

UAV – Unmanned Aerial Vehicle

UKSA – United Kingdom Space Agency

UNDP – United Nations Development Programme

UNEP – United Nations Environment Programme

UNESCO – United Nations Educational, Scientific and Cultural Organization

UNFCCC – United Nations Framework Convention on Climate Change

UNOOSA – United Nations Office for Outer Space Affairs

VSAT – Very Small Aperture Terminal

WGEO – World Green Economy Organization

WORLD GREEN ECONOMY ORGANIZATION

Caribou Space