D2.5 PARSEC Technology Watch Wiki

WP2 – Cross-border and cross-sectoral collaboration

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Document History

Version	**Issue date**	**Stage**	**Changes**	**Contributor**
1.0	14.01.2020	Draft	Version for asking contents	AVAESEN
1.1	17.02.2020	Draft	Version for review	AVAESEN
1.2	21.02.2020	Draft	Version including revision comments from BIOS	AVAESEN, BIOS
1.3	26.02.2020	Draft	Version including comments form EARSC	AVAESEN, EARSC
1.4	28.02.2020	Final	Adding some comments about updating	AVAESEN, EARSC

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Executive Summary

The PARSEC Technology Watch wiki is a wiki – a library of key technologies relevant to the PARSEC focus sectors (Energy, Environment and Food), hosted in a dedicated section of the PARSEC website. This will be a living resource, to be updated as the project progresses.

The wiki library will be available on M10. This deliverable provides an overview of the scope of the Technology Watch Wiki, elements of the technical implementation and a presentation of its content during its first release. Additional content will be produced through the lifetime of the project.

1 Technology Watch Wiki

1.1 Overview

The Technology Watch Wiki aims to provide knowledge to the PARSEC community of applicants and other stakeholders. This knowledge is provided in the form of a review of technology trends on the emerging industries of the PARSEC project (Energy, Environment and Food) and Earth Observation and associated enabling technologies.

1.2 Technical implementation

The technical implementation of this first version has been realised within the PARSEC Accelerator website as a set of pages and functions for filtering and search. The content management system serving the website (WordPress) allows editing and categorising market trends contents as well as suggesting the user related content.

This implementation also serves the Market Trends Observatory, which allows linking market developments and trends with related technologies.

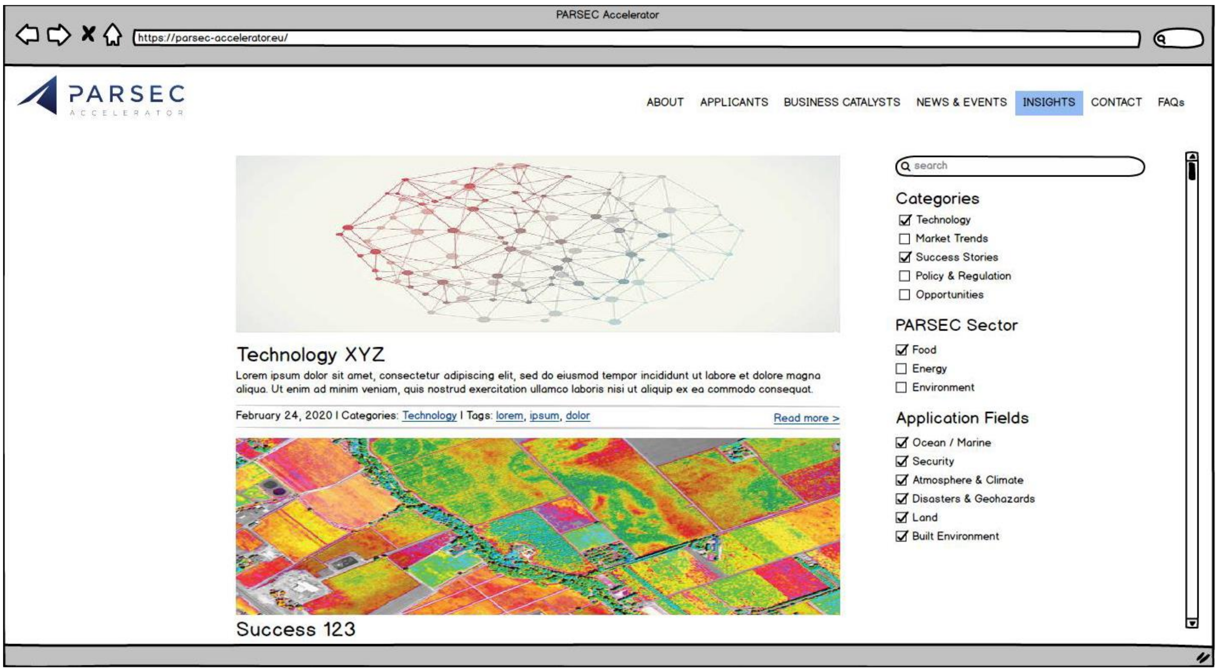

Figure 1. Mockup of landing page for Technology Watch and Market Trends Observatory

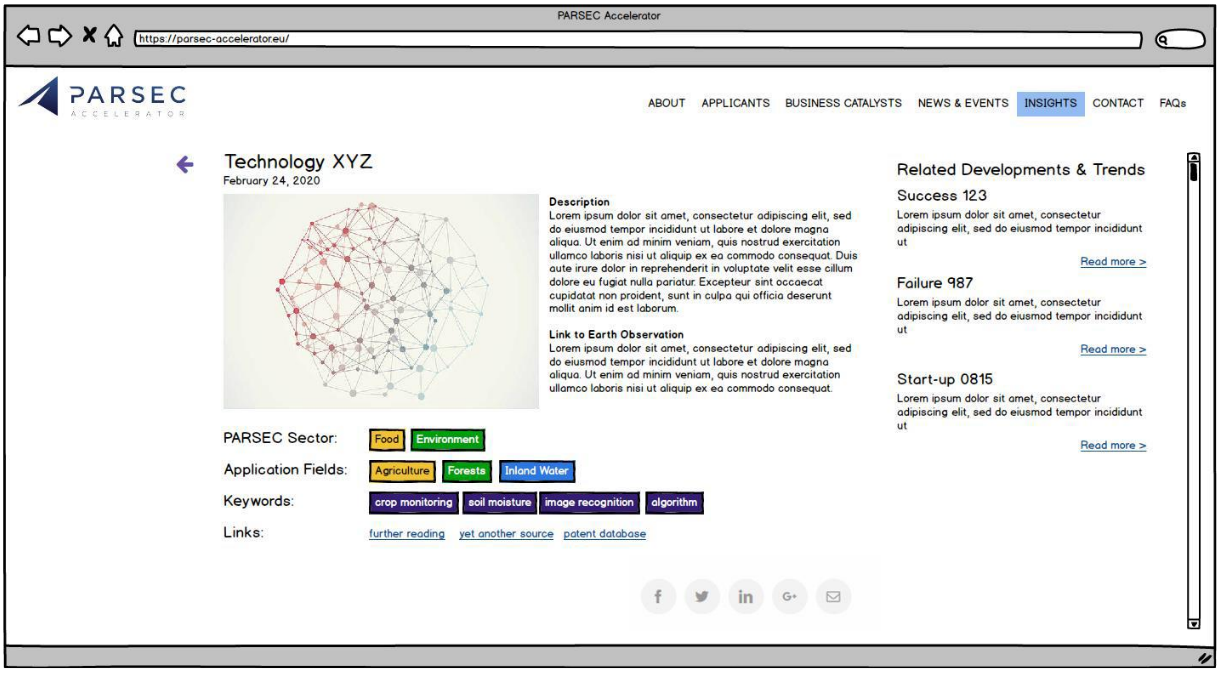

Figure 2: Mockup of Technology View

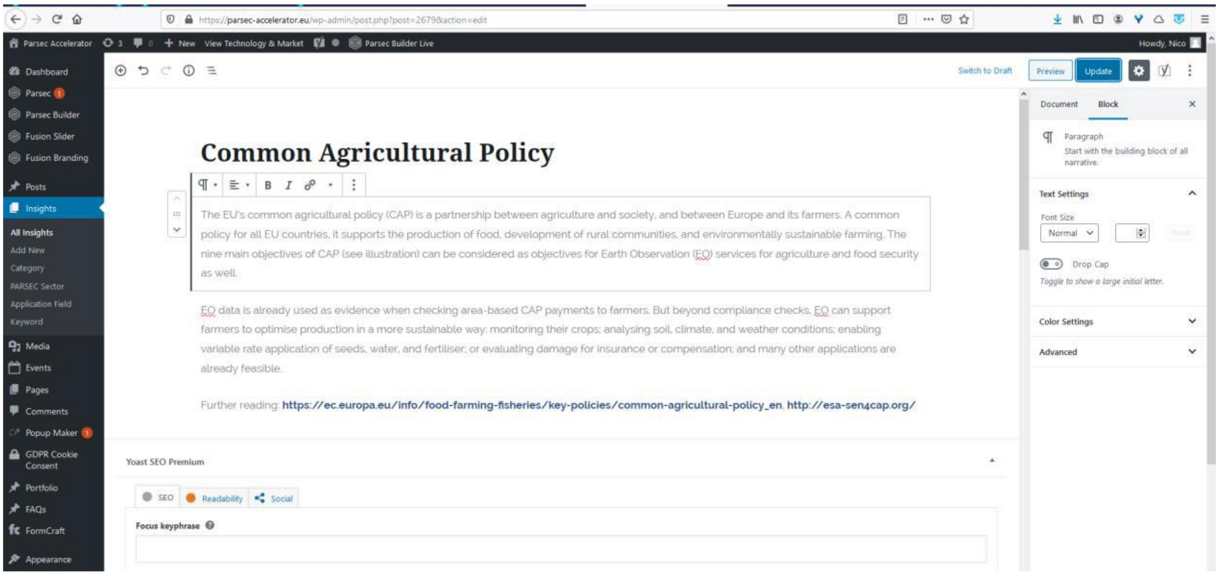

Figure 3: Content Management view (backend) of the Technology Watch Wiki

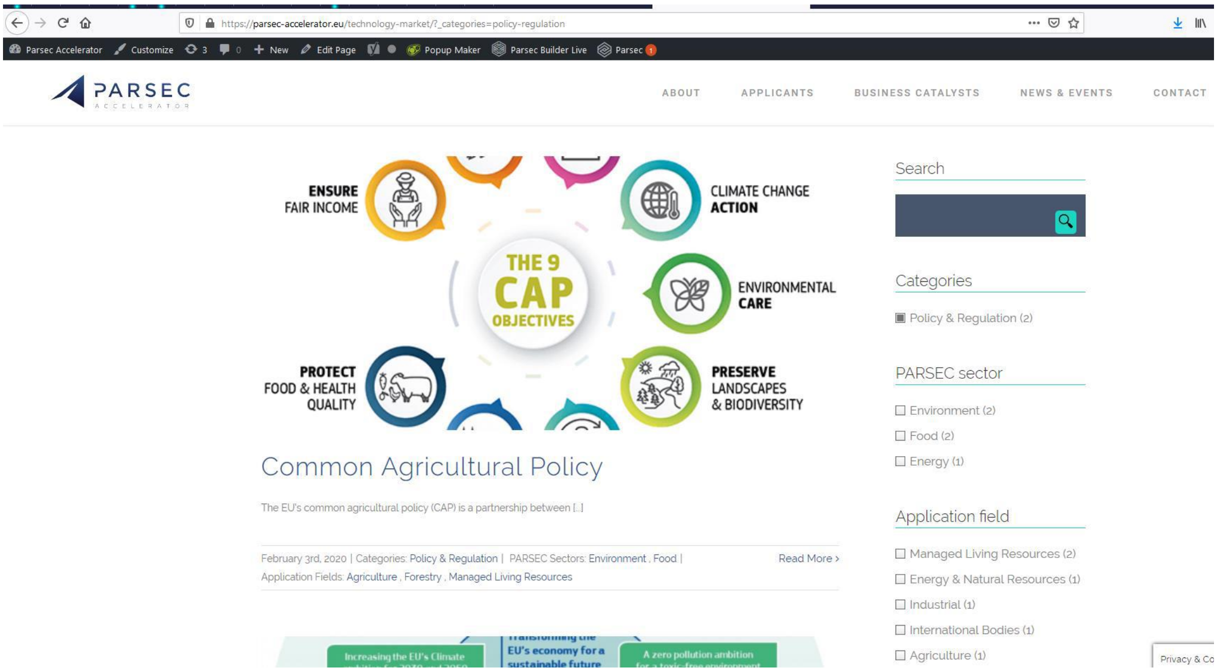

Figure 4: Frontend of Technology Watch Wiki

The Technology Watch Wiki (and Market Trends Observatory) will be available via the following URL: https://parsec-accelerator.eu/insights. A menu item making this link available for the users of the website will be implemented once the first batch of Technology Watch and Market Trends Observatory is finalised and integrated.

The WordPress implementation allows for categorisation and tagging of content, providing the users with possibilities to search using keywords, via recommended related content, as well as filtering by application fields, content types and PARSEC sectors.

1.3 Content Delivery

A structured list of technologies has been developed since November 2019 with a continuous review and selection process. The Technology Watch Wiki has been populated with first contents for the go-live of its website. An editorial process is in place to ensure regular updates with further content throughout the project's duration. This process ensures an equal coverage of all sectors and aspects as well as continuous flow of published content.

The contents are provided by AVAESEN and entered into the system by Evenflow.

Title	Description	EO aspects	Links	PARSEC Sector			EARSC Market Taxonomy																						Keywords
							Managed Living Resources			Energy and Natural Resources			Industrial					Services					Public Authorities				International Bodies		
				Food	Energy	Environment	Agriculture	Forestry	Fisheries	Oil and Gas	Alternative Energy	Minerals and Mining	Utilities	Construction	Transportation	Maritime	Communications	Insurance and Finance	Real-estate Managemen	Retail and Geomarketing	News and Media	Travel, Tourism and Leis	Local and regional plann	Emergency Services	Education, training and r	Security, Defence and m	Environmental, Pollution	Humanitarian Operations	
Gas to Liquids	Gas-to-liquids technology converts natural gas (considered the cleanest-burning fossil fuel) into high-quality liquid products that would be otherwise made from crude oil. Among these products there are transport fuels, motor oils and materials such as plastics, detergents, cosmetics, etc.	detection of resources, pipeline monitoring, monitoring of production facilities			x	x				x			x		x												x		
Hydrogen Fuel Cell Vehicles	Fuel cell vehicles use hydrogen gas to power an electric motor. Unlike conventional vehicles running on gasoline or diesel, fuel cell cars and trucks combine hydrogen and oxygen to produce electricity, which runs a motor. Since they are powered by electricity, they are considered EV, although their range and refueling processes are comparable to conventional cars and trucks.	detection of resources, moniitoring of infrastructure			x	x									x												x		
Autonomous Vehicles	An autonomous car is controlled by an automatic driving system and does not need a physical driver. Three technologies make self-driving cars possible: sensors, connectivity and software/control algorithms. Sensors required are mostly related to safety features, like forward collision warning. Other such as radars and cameras provide also inputs to safety navigation. Regarding the connectivity, it allows cars to have access to the latest traffic, weather, maps, etc. data, used to monitor the car's surrounding environment. finally, software/control algorithms are needed to capture the data from sensors and connectivity and make decisions on steering, braking, speed and route guidance	?				x									x												x		
Liquid Air	The idea consists of using cryogenic air or nitrogen as an energy storage medium. Air turns to liquid when refrigerated to -196°C and can be conveniently stored in insulated but unpressurised vessels. Exposure to heat causes rapid re-gasification and allows it to be used to drive a turbine or piston enegine to do useful work. The main ptential applications are in electricity storage and transport.	asset monitoring			x	x							x		x												x		
Adsorption technology	This technology is based on the sorption of certain substances by molecular sieves with the resulting air mixture separation. The adsorption technology allows efficiently	?				x																					x		

Figure 5: Technologies Repository

1.4 Content (Batch 1)

The online solution has been populated with a first batch of contents which is listed in the following section. Throughout the lifetime of the project, the Technology Watch will be regularly updated with further content. The information regarding Food Sector and the Earth Observation sector and its technologies will be updated directly in the wiki. The content for the two sectors will be based on the one provided in Deliverable D2.4, though the version available online will be developed and extended. Additionally, more detailed connection between the three emerging sectors and the EO will be added gradually to the existent content.

Energy Sector

Energy systems around the world are going through rapid transitions that will bring important changes to the way we fuel our cars, heat our homes, and power our industries. These trends will have widespread implications for businesses, governments, and individuals in the coming decades.

The McKinsey report on Global Energy Perspective 2019 finds three important tipping points in the energy landscape that will come within reach in the next few years:
As the cost of renewables has come down further, many countries will reach a tipping point in the coming five years, where new-build solar or wind capacity is cost-competitive with the fuel cost of existing conventional plants. As a result, we will see a further acceleration of the ramp-up of renewables.
Similarly, as the cost of batteries continues to decline, within the nest 5-10 years, many countries will reach the point at which electric vehicles are more economic than internal combustion engine vehicles. This is true for passenger cars but also for most truck segments.
For the first time, a peak in global carbon emissions is projected, despite the continued economic growth and a growing global population. Triggered by a drop in global coal demand and flattening oil demand, carbon emissions are expected to start to decline by the mid- 2020s.

Cities are at the leading edge of low-carbon innovations and efforts to avert global warming. Big data and IoT (Internet of Things) continue to offer energy efficiency gains for buildings and transportation. Electric and autonomous vehicle technology is leading to advances in grid storage and reduction in emissions. Energy transformation is being modelled in cities, with lessons for regions and nations. Energy companies will partner at the city level to advance smarter, cleaner energy.

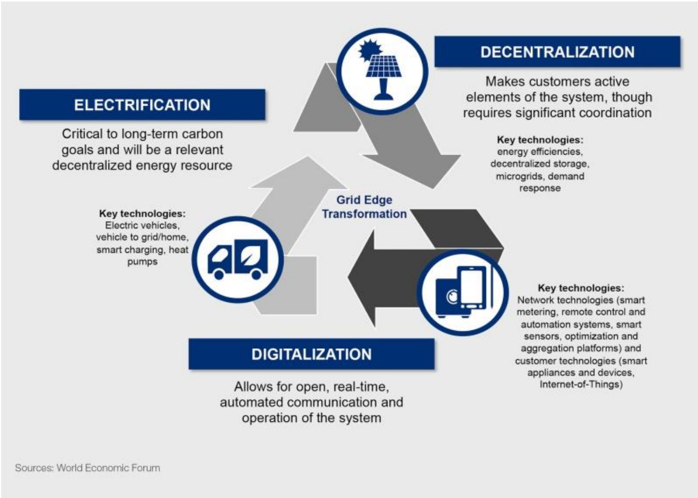

Figure 6: Electrification, decentralization and digitalization are the driving forces behind the transformation of energy systems and act in a virtuous cycle. (Source: World Economic Forum).

Several developments and technology advancements in the energy transition have shown further acceleration. These technology advancements will facilitate the achievement of the global climate strategies and challenges that are driving a global shift in energy systems.

Hereinafter we examine the main technologies related to energy sector, focusing the watch in the following fields: energy production technologies, energy storage technologies and energy distribution and usage technologies.

The following table presents an overview of the studied technologies for each field.

STAGE	SEGMENT	TECHNOLOGIES
PRODUCTION	RENEWABLES	Concentrated Solar Power
		Photovoltaics
		Solar Water Heating Systems
		Turbine manufacturing technologies
		Smart turbine technologies
STORAGE	MECHANICAL	Pumped-storage hydroelectricity
DISTRIBUTION AND USAGE	SELF-CONSUMPTION AND SMART CITIES	Technologies for environmental data acquisition
		Networking and communications technologies
		Sustainable transportation technologies
		Smart cities data management technologies
		Technologies for provision of information, training and dissemination
		Energy efficiency and technologies for integration of renewable energies in municipal buildings

Energy production technologies

Renewables

Technological innovation, cost efficiencies, and increasing consumer demand are driving renewables—particularly wind and solar—to be preferred energy sources. Several trends that are driving this transformation have been analysed. Manufacturers are heavily investing in these new technologies because they anticipate a growing demand for solar and wind power.

Generally speaking, new technologies involving automation, AI, and Blockchain, as well as advanced materials and manufacturing processes, can accelerate the deployment of renewables. The technologies range from those streamlining the production and operation of renewables (automation and advanced manufacturing) to those optimizing their use (AI in weather forecasting), improving the market for renewables (Blockchain), and transforming the materials of solar panels and wind turbines (advanced materials). These technologies support the previous two trends by helping to further decrease costs and facilitate integration.

Automation is dramatically cutting time and costs for solar and wind production and operations. First Solar automated its US manufacturing plant last year and tripled the size of its panels at a cost that undercut its Chinese competitors by 30 percent by transforming production from a hundred-step, multiday process to one that takes just a few steps and hours. Automation also has significant operational implications for offshore wind, which accounts for more planned maintenance outages per installed GW than any other generation technology. In July, the world's largest offshore wind farm deployed fully automated drones and cut the inspection time from two hours to 20 minutes. Looking ahead, crawling robots currently under development will enable automated microwave and ultrasonic inspections of the internal structure and materials in solar panels and wind turbines.

Below, specific technological trends are presented for both solar power and wind power energy.

Solar

Being one of the most abundant and free resources in the universe, solar energy uses the sun visible light and infrared energy, within a specified range of solar radiation spectrum, for energy production. The most widespread solar technology these days is the photovoltaics (PV) that, thanks to the evolution of the digital and electronic era, has improved the manufacturing costs reaching achievable prices even for residential applications.

Apart from these photovoltaics, there are some new solar technologies capable of extracting the energy of the sun.

Concentrated Solar Power
Description of the new emerging technologies: Also known as solar thermal energy, **Concentrated Solar Power (CSP)** has evolved to be used mainly for industrial or utility purposes, being gradually becoming an advantageous alternative to the PV. Currently, Spain and the United States are the world's leading countries applying these technologies, with installed capacities of 2.2 gigawatts (GW) and 1.8 gigawatts (GW), respectively. CSP uses hundreds of heliostats that focus the sunlight onto a large heat exchanger known as receiver. This is located on the top of a tower, containing a pipe containing a heat transfer fluid

that absorbs the heat obtained from the sunlight and carries it to the ground into a thermal energy storage tank. When electricity is needed, this fluid flows through a pipe side-by-side with a pipe filled with water. Then, the water goes into a steam generator where it is transformed in steam by the use of the solar heat. This steam finally generates the electricity through a turbine and the remaining is condensed and stored in a water tank. The remaining heat transfer fluid is stored in a cool fluid tank and it then runs back in order to repeat the cycle.

Different new emerging technologies have been introduced in CSP based on the same principle and having the same components but different way of functioning.

Solar power towers (SPT) offer flexibility in operating temperatures up to 565ºC (1050ºF) and allow to store the heat for up to 15 hours. This technology is still in the development phase. Apart from operating with molten salt, as one of the best heat transfer fluids available, they include other advances such as the utilisation of open air or superheated steam, which decrease the operating costs. However, the main drawback is the significant consumption of water for cooling process and cleaning of heliostats. There are examples of the successful utilization of this technology in Julich (Germany) and Solugas (Spain), both of them utilizing pressurized air coupled to combined cycle turbines. Also in US, SPT are the most used technology, allowing the production of up to 377 megawatts of capacity.

Parabolic Trough Collectors (PTC) is the most commercially mature system as well as the most widespread technology type among CSP (up to 3.5 GW out of the total 4.8GW of installed CSPs worldwide). Parabolic troughs are straight in one dimension and curved as a parabola in the other two, lined with a polished metal mirror. The sunlight entering the mirror parallel to its plane of symmetry is focused along the focal line. The tube containing the fluid runs the length of the trough at its focal line. This technology has also the particularity of the heat transfer fluid used, being thermal oil, capable of achieving operating temperatures between 293ºC (560ºF) and 393ºC (740ºF). However, this oil is known to be highly toxic and flammable. Latest innovations look for increasing the efficiency by using alternative heat transfer fluids like molten salts and air, allowing rising the operating temperatures even higher.

Parabolic Dish Systems have lower application rates in commercial and utility scale projects. Despite having higher solar-to-electric conversion, the maximum power capacity of each parabolic dish is too low, what makes them less attractive when compared with other CSP systems.

Linear Fresnel Reflectors (LFR) present similar problematics to parabolic dish systems. LFR plants do not exceed more than 30MW and use water as the heat transfer fluid, with lower operating temperatures. There are few applications in the commercial sector, but as long as optical efficiency issues continue improving, current trends will continue proving the technical feasibility. Future new projects are planned in India, Australia, China, France and South Africa.

Relevance of EO in these technologies:

EO is instrumental in the successful planning of CSP plants, especially determining suitable sites for their deployment. The search for the most economical sites boasting high Direct Normal Irradiation and yet minimized risk for adverse environment effects can be scaled and automated with Big EO Data analytics relying on a mix of remote sensing and in-situ data.

Application sectors:	**Keywords:**
Energy production, renewable energy, solar power	Concentrated Solar Power, Solar Power Towers, Parabolic Trough Collectors, Parabolic Dish Systems, Linear Fresnel Reflectors, renewable, solar, inspection, maintenance, site selection, irradiation

Main stakeholders doing R&D:	Main stakeholders in the market:
BP Solar, Omnion Power Engineering, Siemens Solar Industry, Shell Solar Industries, Spectrolab	Aalborg CSP, Abengoa, Acciona, GlassPoint Solar, SENER, Royarl Tech CSP, Torresol Energy, Feranova, Novatec Solar, HelioFocus

Photovoltaics

Description of the new emerging technologies:

The market of solar photovoltaics has experienced an important expansion in the last years. The costs of silicon solar cells have dropped significantly, so solar photovoltaics systems have become easily obtainable for house owners. New solutions and technologies are continuously being studied.

Solar roofs are one of the most interesting new trends. Solar roof tiles and other modules integrated in buildings for some time, but the concept of solar roof itself is new. Tesla has been working on them for removing any sort of visual setback that homeowners may dislike about photovoltaic solar panels while providing a reliable source of solar electricity. The full roof coverage implies a solution where photovoltaics are directly incorporated into the structure of the house, acting both for aesthetic, constructive and electrical purposes.

Spray on solar cells is another key development. Since Mitsubishi Corp. decided to invest in the research of this technology, the idea has been circling in the industry for some time. The last development has been the Perovskite, made mostly of carbon and hydrogen. This technology allows to harvest light in the form of liquid solar cells, can be placed on diverse surfaces of technically any shape and no furnace is needed. Once dried and solidified, perovskite solar cells can act as semiconductors and generate electricity. Manufacturing and material costs are cheaper than silicon solar cells. However, this technology shows major limitations mainly in the installation of large-area spray solar cells and the controlled integrity. This technology can be also used for the manufacture of various layers of thin-film solar cells.

If silicon technology cannot achieve higher efficiency values, then maybe light-sensitive nanoparticles might. In this sense, **colloidal quantum dots** are believed to be cost-efficient and flexible materials, ideal for the manufacturing of photovoltaic solar cells. This technology had been tested before, with n-type and p-type semiconductors and unfortunately it does not function outdoors. New approaches look to work outdoors as well.

Until the moment, solar power generation has been limited because the spectrum of solar radiation used to generate electricity is only the visible light. New types of improved solar cell aim to achieve efficiency values beyond the 33.7 percent. MIT scientists came up with the idea of introducing a light concentrator known as **absorber-emitter**, made of carbon nanotubes, that turns sunlight into the heat when temperatures reach 1000ºC (1832ºF). Then, a layer from the emitter radiates the energy back out as light narrowed to the bands that photovoltaics can absorb. By now, only one prototype has been developed in the MIT laboratory.

Relevance of EO in these technologies:

EO is necessary for the successful planning of photovoltaic sites, like with CSP, especially with larger installation. Even on smaller scale such as solar roofs, EO analytics provides the tools to accurately determine the cost-effectiveness of such investments. Satellites can be also used to monitor the efficiency of the installation (comparison of the irradiation and the energy produced) and to track damages. EO is also uses in the process of audit for the installations, and some municipalities relay on satellite images to identify illegal or to inspect the existent installations in an objective manner.

Application sectors:	Keywords:

Energy production, renewable energy, solar power	Solar roofs, spray, light-sensitive nanoparticles, colloidal quantum dots, absorber-emitter, carbon nanotubes, renewable, solar, photovoltaics, inspection, maintenance, site selection, irradiation
Main stakeholders doing R&D: Shell Solar Industries, Solar Cells, Photovoltaics International, Global Solar Energy	**Main stakeholders in the market:** BP Solar, Isofoton, Tamesol, Zytech Solar, Mitsubishi Electric, First Solar, Bosch, Conergy

Solar Water Heating Systems	
Description of the new emerging technologies: **Solar Water Heating Systems (SWHS)** are the most widely used type of Solar Heating and Cooling Systems. These systems pass cold water through a pipe that goes into a heat exchanger. From the exchanger, solar collectors carry heat transfer fluid, which is heated from the incoming infrared radiation from the sun. Then, it is the heated fluid what warms up the stored water that is used to heat or cool homes. Solar thermal heating and cooling is a well-known and still evolving technology. Among recent developments, it is the innovation of the district solar heating network in Denmark, showing optimized performance. Further development is performed to achieve advanced solar energy collectors. **Two main types of solar collectors** are currently in the market: **unglazed and glazed** (flat plate and evacuated tubes). Glazing is preferable as collector's efficiency can be further improved by adding transparent insulation materials to the collector's surface, allowing in this way the reduction of heat losses between the panel and the environment. The newest development can be found in **new designs** like thermoplastic natural rubber tubing on absorber plates with foam insulation and water as the working fluid. Through this combination, 72% efficiency and 65ºC tank temperature can be reached. Other benefits are the low manufacturing costs, the high performance and the high durability. Further developments are focused on the heat transfer fluid, looking for fluids with low freezing point in cold climates and high boiling point in hot climates. These properties together with others like viscosity, and thermal capacity play a key role in the overall performance of the system. Some examples of fluids that are being analysed are the air, oils, hydro-carbon, glycol/water mix, refrigerants, etc.	
Relevance of EO in these technologies: EO can be used to determine the right location for the installation of heating system. Satellite data and its modelling allow to foresee the irradiation and hence to choose the site with the potentially highest irradiation. Depending on the infrastructure, satellite images can be also used to monitor its efficiency and condition.	
Application sectors: Energy production, renewable energy, solar power	**Keywords:** Solar water heating systems, solar collectors, glazed, unglazed, new materials, renewable, solar, inspection, maintenance, site selection, irradiation
Main stakeholders doing R&D: Ibersolar Energía, Solaris Energía Solar, Osiel S.L., Giacomo & Cidete Technologies	**Main stakeholders in the market:** Zytech, Acpsol Energia Solar, Arpi Solar Systems, Energy Panel, Kom Sol International World Wide Distribution, Novasol Sistemas Energéticos, Promasol Energía Solar

Wind

Wind turbine manufacturing technologies	
Description of the new emerging technologies: Wind energy production through wind turbine functioning is being boosted by the manufacture of **longer blades** and **taller towers**. Turbines are evolving to more powerful, efficient, durable and cost-effective components. Research in important innovations will allow easier and cheaper turbine manufacturing, **intelligent turbines** will be created capable of collecting and interpreting **real-time data**, and wind plant modelling, adjustment and configurations will maximize wind harvest. Most ambitious R&D seeks to create a rotor blade longer than 650 feet for a 50-MW offshore wind turbine, 2.5X longer and over 6X more output than the largest blades and turbines now in operation. Through the introduction of a Segmented Ultralight Morphing Rotor (SUMR) technology, an aerodynamically-sophisticated load alignment, peak stress and fatigue on rotor blades could be substantially reduced, making the gigantic turbine structurally and economically feasible. An important barrier can be found in the transportation by land under bridge overpasses. In response, it is being studied the possibility of including welding process to build taller steel towers onside and bypass the travel and cost constraints. Other innovations focus on the manufacturing techniques and materials selection. The challenge is making larger and taller but not heavier and costlier turbines. One approach is to make the bigger blades lighter to lessen aerodynamic and gravity loads on the other turbine components, like the drivetrain, and lessen also material costs. In that sense, the way of making the blades is changing. Sandia and Oak Ridge National Laboratory are investigating 3D printing to manufacture turbine blade molds, eliminating costs and time in mold manufacture.	
Relevance of EO in these technologies: As for all renewable energy power plants, EO can be used to determine the best location for the plant, nevertheless, the turbines can be helpful for the EO as well. Intelligent turbines would provide real-time in-situ data on various parameters, especially wind speed, air temperature, humidity, which could be useful when fed into EO databases and mixed with data from other sources.	
Application sectors: Energy production, renewable energy, wind power	**Keywords:** Long blades, large towers, intelligent turbines, renewable, wind, sensor, in-situ
Main stakeholders doing R&D: Vestas, Goldwind, Enercon, Siemens, Suzlon Group	**Main stakeholders in the market:** Siemens, Vestas, GE Renewable Energy, Enercon, Nordex SE, Senvion SE, Goldwind, Sinovel Wind, Suzlon, Gamesa Eólica, Ecotècnica/Alstom Wind, Iberdrola, Acciona Energy , MTorres

Smart turbine technologies
Description of the new emerging technologies: Current trends move to smarter turbines and plants. Smarter turbines are able to sense and optimize energy capture while knowing the state of the turbine's health. For instance, the wind

<table>
<tr><td colspan="2">farm model developed by GE pairs 2-MW wind turbines with a digital twin modelling system that can assemble up to 20 turbine configurations at every wind farm pad for peak power generation. Embedded turbine sensors gather and analyse real-time data on factors such as temperature, misalignments or vibrations and relays it to advanced networks that make adjustments to improve efficiency.

New technologies have also emerged for wind resource assessment for studying the suitability of the site for a wind farm construction. The minimum average wind speed potentially economically viable will vary with the class of wind turbine and the current/predicted cost of electricity in the region. The knowledge of the long-term average wind speed, coupled with considerations of favourable topography, and the proximity to existing transmission infrastructure, will be the most important factors for identifying adequate sites. After that, detailed measurement campaigns of at least one year in duration are needed, from a met mast or LIDAR. This is a challenging offshore process for collecting information regarding hub-height and rotor-layer wind speed information over each season, so that annual energy production at that site can be assessed. Other information is also provided by met masts or LIDARs, for example, about the profile of wind speed with height at that location, along with information about the turbulence, information that could be useful for example for banks to decide whether invest or not for a proposed wind project.</td></tr>
<tr><td colspan="2">Relevance of EO in these technologies:
Remote sensing radar data, such as Sentinel 1, are supplemental to the ground LIDAR in providing coarser context on a planetary scale. Combining and exploiting both is possible with various EO tools, e.g. see BigDataCube for a relevant use-case on off-shore wind parks in the North Sea.</td></tr>
<tr><td>Application sectors:
Energy production, renewable energy, wind power</td><td>Keywords:
Digital twin modelling, turbine configurations, embedded turbine sensors, advanced networks, met mast, LIDAR, renewable, wind, IoT, site selection</td></tr>
<tr><td>Main stakeholders doing R&D:
Vestas, Goldwind, Enercon, Siemens, Suzlon Group</td><td>Main stakeholders in the market:
Siemens, Vestas, GE Renewable Energy, Enercon, Nordex SE, Senvion SE, Goldwind, Sinovel Wind, Suzlon, Gamesa Eólica</td></tr>
</table>

Energy storage technologies

A wide array of storage technologies has been developed so that the grid can meet everyday energy needs. Since the discovery of electricity, we have sought effective methods to store that energy for use on demand. Over the last century, the energy storage industry has continued to evolve, adapt, and innovate in response to changing energy requirements and advances in technology.

Energy storage systems provide a wide array of technological approaches to managing our power supply in order to create a more resilient energy infrastructure and bring cost savings to utilities and consumers. To help understand the diverse approaches currently being deployed around the world, we have divided them into five main categories:

Batteries – a range of electrochemical storage solutions, including advanced chemistry batteries, flow batteries, and capacitors
Thermal – capturing heat and cold to create energy on demand or offset energy needs

Mechanical Storage – other innovative technologies to harness kinetic or gravitational energy to store electricity
Hydrogen – excess electricity generation can be converted into hydrogen via electrolosis and stored
Pumped Hydropower – creating large-scale reservoirs of energy with water

Few of them show a possible relation to EO data, for example, in the case of mechanical storage described below.

Mechanical

<table>
<tr><th colspan="2">Pumped-storage hydroelectricity</th></tr>
<tr><td colspan="2">Description of the new emerging technologies:
Pumped hydroelectric energy storage is a type of hydroelectric energy storage used by electric power systems for load balancing. The energy is stored in the form of gravitational potential energy of water, pumped from a lower elevation reservoir to a higher elevation. During periods of high demand of electricity, the stored water is released through turbines to produce electric power. This technology allows energy from intermittent sources such as solar and other renewables, or excess electricity from continuous base-load sources to be saved for periods of higher demand.

Significant advances have been achieved for the pumped storage technologies since its beginning. Current technologies provide improved efficiencies with modern reversible pump-turbines, adjustable-speed pumped turbines, new equipment controls such as static frequency converters and generator insulation systems, as well as improved underground tunnelling construction methods and design capabilities. Among the benefits allowed, it is the possibility of tuning of the grid frequency at night or during system disturbances or anomalies, as well as the use of fluctuating renewable wind or solar energies to pump water to the upper reservoir. Pump operation with adjustable-speed units is extended in comparison to single-speed units, enabling more real-time response to grid conditions.</td></tr>
<tr><td colspan="2">Relevance of EO in these technologies:
EO technologies are capable of improving and scaling the search and analysis of suitable sites, similar to the cases of other large-scale energy projects.</td></tr>
<tr><td>Application sectors:
Energy storage, energy production , hydroelectricity</td><td>Keywords:
Mechanical storage, pumped hydroelectric energy, modern reversible pump-turbines, underground tunnelling, new equipment controls, site selection, hydropower, inspection, maintenance, dam integrity</td></tr>
<tr><td>Main stakeholders doing R&D:
Pumped Hydro Storage</td><td>Main stakeholders in the market:
Pumped Hydro Storage</td></tr>
</table>

Energy distribution and usage technologies

Self-consumption and Smart Cities

In a context of increasing energy prices, households and businesses using solar electricity rely on a power source the cost of which will remain fixed for the decades to come. Self-consumption does not only provide cheap electricity to people; it also protects them against volatile energy prices. Energy self-consumption increases retail competition and helps market transformation and makes consumers active players of the energy transition, a key objective of the Energy Union. Because it leads to concrete economic benefits, making the best use of on-site generation, self-consumption is considered a key driver for demand-side flexibility with the development of solutions such as storage, smart appliances and more flexible contracts for consumers.

Individual self-consumers are the final consumers entitled to consume and store the electricity they have produced within their premises and to sell this electricity. Renewable self-consumers are limited to producing electricity from renewable sources, whereas the definition of active customers also explicitly includes activities beyond energy generation such as the participation in flexibility or energy efficiency schemes.

The development of a sharing economy in the recent years has led to an increased interest in direct sharing of electricity between producers or self-consumers and other final customers. This collective self-consumption has been already recognised in certain national legal frameworks such as France and Austria or within pilot projects, but the concept is still formally being recognised in the EU-level legislation.

Additionally, there exists the concept of Energy Community, which has been already introduced into the European legislation, differentiating between Citizen Energy Communities and Renewable Energy Communities. These energy communities are entities set up as a legal person that are defined by their structure and effectively controlled by their shareholders or members. The primary objective of the energy communities is to provide environmental, economic and social community benefits rather than financial profits. Renewable Energy Communities are limited to renewable energy technologies while citizen energy communities are technologically neutral. Renewable energy communities can be active in all energy sectors for the production, consumption and selling of renewable energy. In the case of citizen energy communities, their activities are limited to the electricity sector and are dedicated to electricity generation, distribution and supply, consumption, aggregation, storage or energy efficiency services, charging services for electric vehicles, etc.

The technologies needed to increase self-consumption are available today but have been developed in their own silos. Few integrated solutions exist in the market, combining technological solutions to produce, store and share energy from renewable sources.

Regarding Smart Cities segment, world's population living in urban areas have increased in the last decades. By 2030, it is expected that roughly 66% will live in those urban areas. These numbers represent a major challenge to cities building and management bringing the opportunity to improve the lives of billions of people; a challenge that cannot be faced without new technological trends, such as Cyber Physical Systems, 5G or data analytics. New approaches and solutions will be applied for enhancing city transportation, water and waste management and energy usage, among others.

"Smart cities" term has become increasingly popular recently. A smart city is an innovative city in which the information and communication technologies (ICTs) and other means are used to improve the quality of life, the efficiency of the urban operation and services, and their competitiveness, while ensuring that the needs of the present and future generations regarding the economy, society and environment, are covered.

Thus, smart cities not only involve new technologies, but also do count on the participation of many stakeholders including citizens, city authorities, local companies and industrial and community groups. Ultimately, smart cities can be considered as complex ecosystems counting on three main pillars, being: technological, institutional and human aspects. Any smart cities' goal has to create value for the entire ecosystem, whether this value is financial, life quality, health, education or time.

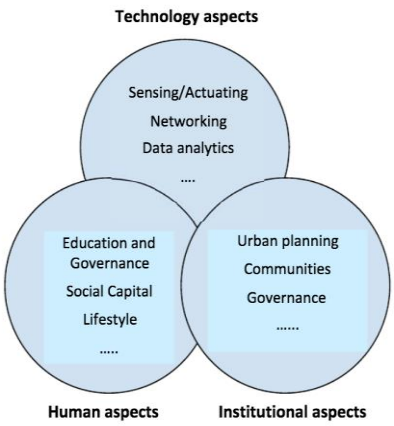

Figure 7: Main pillars of the smart cities ecosystem (Source: Lea. R.J. Smart Cities: an overview of the technology trends driving smart cities. IEEE press. 2017 Mars 15.)

Continuing with the technology scanning, further on this document focuses on the technological aspects related to the concept of smart cities, especially the technology trends that are shaping how smart cities are evolving. Major players operate in several areas, providing solutions that complement, and even overlap, other players. Many of those companies lack the scale to achieve end-to-end solutions on their own and need to work in collaboration with partners from other technology segments. In this sense, five different segments can be identified:

- **IT players:** IP networks, software, analysis, technology integration, security, etc.
- **Energy & Infrastructure:** power electronics, renewable, smart & micro grid, substation automation, etc.
- **Automation & Building Control:** building automation, energy management, device connectivity, monitoring & sensing, security, etc.
- **Governance:** e-governance, open-data, citizen engagement, privacy & security, etc.
- **Telecom:** broadband & internet technologies, mobile telephony, networked IT services, monitoring & sensing, security, etc.

Due to the diversity of subsystems involved, e.g. transportation, health, energy, etc., a system-of systems approach is needed to address the needs of both the city and its citizens. As previously said, the cooperation of multiple companies is the usual case, combining solutions and technologies, from low-level sensors/actuations, effective data communications, data gathering and analysis, and domain specific applications.

An analysis of the key technologies, challenges and enablers is included below for those detected technologies with possible relations to EO data.

Technologies for environmental data acquisition
Description of the new emerging technologies: The environmental change affects cities and their inhabitants more regularly, bringing new challenges for city planners. Among those, there is a need to improve air and water quality and control noise pollution looking to create a healthy and enjoyable environmental for city

inhabitants. For that, environmental monitoring and management is gaining importance, as understanding and managing the environment and its impacts could increase amounts of regulation and activities to reduce pollution. In this line, **cyber-physical systems and the IoT**, understood as the connection and virtual representation of physical devices to the Internet, are key in the growth of smart cities. For years, traditional cities infrastructure has been monitored using proprietary technologies maintained as individual silos. With the introduction of the IoT, the infrastructure is being connected using open standards (e.g. OGC, W3C) over **open standard protocols such as HTTP(S)**. Additionally, the reduction in the equipment's size and costs has allowed the expansion of the sensing to more parts, enabling higher fidelity sensing. **IoT sensors** are able to give accurate real-time data on the environment around us. These technologies allow the measurement of many environmental parameters such as air and water quality, weather, noise, pollen, smoke and other attributes that may affect quality of life in a city, including those related to disaster management, such as earthquake and floods. Cities planning to deploy IoT based environmental monitoring need to consider some criteria. First, data accuracy, which depends on a number of factors. Cities have to decide how to best balance the accuracy of environmental monitoring by understanding what the data will be used for, against the cost. Sensor location is also very important, having the possibility of placing them in fix or movable locations. The variability in local environmental conditions has a direct impact on environmental data readings, so data analytics is also applied to identify possible variations in readings. With all the previous, environmental monitoring equipment based on IoT requires a **strong communication network** to ensure that services can operate effectively and managing platforms. IoT data provide additional value and intelligence when integrated to get a complete view of local environmental conditions and what maybe affecting them. **IoT big data** allows the sharing of IoT and context data so that solutions utilising data from multiple sources can be developed.
Relevance of EO in these technologies: These technologies are a very relevant source of data for EO datacube systems, which enable fusion with further EO data from multiple federated sources into higher-level added-value products. There have already been various successful crowd-sourced efforts to environmental data acquisition, e.g. on particulate matter, temperature, humidity.

Application sectors:	**Keywords:**
Energy self-consumption, smart cities, smart grids	Energy efficiency, Self-consumption, cyber-physical systems, IoT, open standard protocols, web techs accessibility, communication network, big data, environment, air quality, in-situ
Main stakeholders doing R&D:	**Main stakeholders in the market:**
VITO, Nesa, Dewesoft	Eléctricas Hermanos Campos S.L., Robert Bosch, Electronics Trafic S.A., Ampere Power Energy, Azigrene Consultores, Cumulus City, Endurance Motive S.L., Atrae Foro de Energía, SENSA Servicios Eléctricos, SoluciónCO2Zero, Labaqua

Networking and communications technologies
Description of the new emerging technologies: Energy management needs a **communications infrastructure** in order to connect infrastructure, with devices and people, in such a way that data gathering and services delivery is possible. The complexity of the technological and service ecosystem requires a holistic approach to

networking and communications. For that, smart cities count on a range of technologies from **low bandwidth wireless technologies** such as Bluetooth LE and ZigBee, to **fiber optics**. Among those, there are some critical trends that will affect the near future of smart cities, being **Low-Power WAN technologies**, **3/4G evolution** and **5G networking**. Low-Power WAN technologies fit the technological niche between personal/local area networking such as Bluetooth LE, ZigBee and WiFi, licensed cellular networking such as existing 3/4G and the evolution to 5G. Despite they can be considered a stopgap before the deployment of 5G, they are a subject of interest being subject to multiple trials. Regarding 3/4G evolution, 5G standards are not expected to be fully deployed until 2020, so in the meantime, initiative are focused on evolving the existing cellular technologies, looking for better energy efficiencies, cost reductions, better penetration/density in all critical for IoT situations. 5G networking is the next-generation networking, aiming to address the needs of smart cities with higher bandwidth, delivery and performance guarantees, adaptability, energy efficiency and real-time capabilities. In the long term, 6G is also expected to be commercially launched, in 2030. 6G is being developed in response to the increasingly distributed radio access network (RAN) and the desire to take advantage of the terahertz (THz) spectrum to increase capacity and lower latency. Additionally, two critical technology trends refer to the combination of multiple evolving technologies, i.e. software-defined networking (SDN) and network function virtualization (NFV).
Relevance of EO in these technologies: EO benefits tremendously from improved network capabilities, especially due to the massive amounts of data generally involved. Network speed is a main bottleneck in many EO analytics cases, especially in large federations. For example, transferring 600TB of climate data from DWD (German Meteorological Service) to the supercomputer at FZ Jülich in the DeepRain project has taken months to complete in 2019.

Application sectors: Energy self-consumption, smart cities, smart grids, energy communities	**Keywords:** Energy efficiency, Self-consumption, communication infrastructure, low bandwidth wireless techs, fiber optics,Low-Power WAN technologies, 3/4G evolution, 5G networking, Big Data
Main stakeholders doing R&D: Cellnex Telecom, Hitachi Ltd, Sterlite Tech	**Main stakeholders in the market:** Eléctricas Hermanos Campos S.L., Electronics Trafic S.A., WITRAC, GMV, Nethits Telecom Group

Sustainable transportation technologies
Description of the new emerging technologies: **Autonomous driving**, **connected vehicles**, **electrification**, **ride sharing** and **mass-transit systems** are set to change the face of mobility at cities 11. Zero-emission vehicles are attributed to the transportation options not resulting in harmful emissions during vehicle operation. Typical examples are **electric** (battery-powered) **vehicles** and **trains**, **hydrogen-fuelled vehicles**, and **human/animal powered transportation**. The battery technology for electric vehicles is based on charge/discharge cycles, that is, the battery is charged beforehand using an electricity source and is discharged when the vehicle is in operation. In the case of the hydrogen-fueled vehicles, they are typically based on fuel cell technology. This implies electrochemical conversion of fuel energy into electricity, with water and heat as the only emissions. At a higher level, improving traffic control could contribute to the reduction of pressure on the infrastructure, improve the air quality and make cities more liveable. To this aim, **alternative models of transportation**, **active traffic management** and **connected vehicles into an**

intelligent transportation system are being studied. The focus of smart transportation is to connect the different transportation modes into an integrated system in order to provide the citizens with valuable information to make the right choices of form of travel. Smart transportation allows the control of the flow of traffic and provide added value with best routes for emergency and low enforcement personnel. Cities rely on a massive **system of IoT sensors, cameras and mobile devices to gather data** about incidents, traffic and weather. A multitude of devices are connected to **networks** acquiring massive amounts of data that is managed through **high-tech transactional services, unified communications, cloud, big data and cybersecurity services.** Building smart transportation networks involves, as first step, connecting the traffic light systems. Connecting all the data captured **in one single data management service** allows for flow optimization based on traffic routing. Then, the selected traffic user groups (buses, trucks, cars, etc.), are connected by installing **on-board unit**s. Also **device health management services** are provided to monitor and manage smart devices and sensors. A managed **multi-cloud service** is use for data handling to ensure data accessibility. Also innovation in last mile freight and parcel delivery solutions could yield significant benefits for cities by reducing traffic congestion in urban centres, improving public health by lessening greenhouse gas emissions (GHG). From manufacturer's plant or warehouse or a supplier or retailer location, the last mile of delivery is the final stage in the shipping process, culminating with arrival of the package or good to the customer's destination. Innovation in short distance deliveries represents a major opportunity for smart cities. According to a study of the Técnico Lisboa, any deliveries in urban areas are less than 5km and at least a 25% could be accomplished via bicycle or non-motorized vehicles. **Human-powered, robotic and semi-autonomous vehicles** should have an important role in the parcel delivery role. Other improvements would be the design of **advanced algorithms and analytics** such as integrated inventory management, dynamic routing, courier collaboration and proof-of-delivery tools. Looking to the future, **drones and autonomous vehicles** are expected to be integrated. Also **autonomous ground vehicles (AGVs)** with parcel lockers would be introduced.	
Relevance of EO in these technologies: EO is instrumental to efficient transportation. The canonical example today is Google Maps, and a plethora of similar apps, all of which improve and minimize travel time and distance. They are already self-adapting to live traffic data and weather conditions contributed on the fly by their users. The main problem is that in most cases the tools and data are proprietary (exception being OpenStreetMaps). Converging to an open platform with free access would be extremely beneficial, with positive effects rippling through many industries other than transport.	
Application sectors: Smart cities, smart grids, logistics	**Keywords:** High-tech services, multi-cloud, big data, on-board device, advanced algorithms and analytics, drones, mapping, GNSS
Main stakeholders doing R&D: Dewesoft, MAHLE, GMV, Nissan/Renault alliance, Indra, GreenFlux, ImagineCargo, Cargohopper, GLS	**Main stakeholders in the market:** Power Electronics España S.L., Eléctricas Hermanos Campos S.L., Sernoven S.L., Robert Bosch, Electronics Trafic S.A., STS Control, Pavener Servicios Energéticos, Cumulus City, Endurance Motive S.L., Uponor Hispania S.A.U., Enersoste S.L**., GMV, Vadecity, MAHLE**

Smart cities data management technologies
Description of the new emerging technologies: **Smart cities** are based on well connected, sustainable and resilient technologies allowing the information to be available and findable. Significant amounts of data are generated and two key

trends make this data collection and availability possible: **Internet of Things (IoT) and Open Data**. All the smart solutions in smart cities are based on **IoT** where they are connected and smart enough to decide their performance. For that, data is collected through **data-acquisition devices** such as sensors. Processes are improved based on its environment and for a control system to be aware of the environment, an array of sensors usually is responsible of the collection of the required data. Sensors capture parameters of a physical nature to an electronic signal, which can be interpreted by humans or can be fed into an autonomous system. Among these signals, light, pressure, temperature, humidity and moisture are included. The data shows the characteristics of **big data**: high volume, real time (velocity), extremely heterogeneous in sources, formats and characteristics (availability). The integration of these technologies result in intelligent cities, and this intelligence is translated to smarter and safer cities. Big data can, if managed and analysed well, offer insights and economic value that cities and city stakeholders can use to improve efficiency and lead to innovate new services looking for improving the lives of citizens. For example, through **ICTs and cloud computing** it is possible to perform the analysis of the energy demand pattern and allow the resource optimization with the help of **analytics and deep learning**. Every device involved in the smart city need to be connected to each other allowing managing resources of a megacity population. At this point, it is also important the role played by the **geospatial technology**, which provides location allowing pinpointing exactly on the need so that better solution can be created. Whichever is the solution, smart cities are digital revolutions generating a huge amount of data that need to be processed and generate information in return. For that, **Artificial Intelligence** makes sense out of the data, for example, allowing intelligent traffic management or a better management of the power grid. **Data cube systems (e.g. rasdaman)** support this by making global EO time-series data ready for convenient and scalable on-demand analytics and fusion with federated data sources. Regarding **blockchain**, its application is new to smart city concept and secures data flow. Its integration into smart cities could improve the connection of all the services while boost security and transparency. Blockchain is expected to influence cities through smart contracts, which help with billing, processing transactions and handling facilities management. This technology can also be used for energy sharing.	
Relevance of EO in these technologies: Smart cities rely heavily on EO data as can be inferred from the description above, so it is highly relevant to EO.	
Application sectors: Smart cities, smart grids	**Keywords:** AI, blockchain, ICTs, cloud computing, analytics and deep learning, open data, big data, data acquisition devices
Main stakeholders doing R&D: Schneider Electric, LG Chem, GMV, SAP, Emergya, Data Republic, P-Pulse, Entry-Scape, Vawlt, Sigfox, Virtual Open Systems, rasdaman	**Main stakeholders in the market:** Robert Bosch, Electronics Trafic S.A., Ampere Power Energy, Indertec, Azigrene Consultores, Pavener Servicios Energéticos, Cumulus City, Endurance Motive S.L., Horizon Proyectos Energéticos – KLENERGY, Atrae Foro de Energía, Jonsok Autoconsumo, Nayar, WITRAC, GMV, Rivas Robotics, Mafelec, SENSA Servicios Eléctricos

Technologies for provision of information, training and dissemination to citizens in the field of energy efficiency

Description of the new emerging technologies:

Citizen engagement is a complementary aspect of smart cities related to the support of greater engagement in an attempt to tap into the collective intelligence of cities as well as better understanding their daily acts and needs.

Currently, bigger priority in energy efficiency oriented training and promotion activities is given to the implementation of modern technologies and solutions for new building construction. Across all the countries of the Europe region, the buildings sector accounts for approximately one third of energy consumption, and 40% of CO2 emissions (UNECE 2018). The building sector presents a unique opportunity to improve energy efficiency substantially and, for that, national public policies include a variety of mechanisms which are meant to encourage increasing building energy efficiency, including consumer information programmes.

Local governments should publish city-level data demonstrating both decreased energy costs and higher income associated with various levels of energy performance certification to promote building energy efficiency investments. Governments also should scale up effective promotion and awareness campaigns which are essential to encourage consumers to purchase appliances labelled with high energy efficiency ratings. **Sustainable Energy Action Plans** are enhanced and improved in order to reach energy savings and the national targets of public buildings' energy efficiency. For that, a technologically oriented methodology focuses on increasing cooperation among public authorities through Joint Actions.

Energy performance certificates are widely implemented and also mandatory in some cases. Buildings through European Union can be rated and certified for their efficient use of energy. Those building with higher ratings tend to earn substantially higher premiums. In this way, owners are able to earn a profit on energy efficiency investments from both reduced energy consumption and increased economic rents. This should be further promoted by collection and publishing demonstrative data. Some countries also promote voluntary energy labelling scheme for building construction products, not covered by the European energy label. The implementation of the scheme is based on public events, training and capacity building for manufacturers and suppliers.

Also training activities are developed and implemented aiming to increase the motivation and awareness of managers of municipal departments or public buildings, staff responsible for the daily energy management, maintenance and operation of the public buildings, municipality staff in charge of developing and controlling public buildings budget, etc. Energy efficiency related **"knowledge hubs"** are created to provide world-class training on energy efficiency, based on new training programmes, business plans and up-to-date training equipment for a set of training and consultation centres.

Codesign and user-centric design processes are developed to engage citizens in the ideation, design and delivery of new services. This citizen-centric approach has been already tried in some countries.

Regarding the specific technologies themselves being employed for user engagement:

Digital tools (mobile and web service tools) are developed and provided to customers looking for ensuring transparency and full access to information in the liberalized energy market. These tools help consumers to find clear information about energy offers, comparing among all variety of tariffs on the energy market and allowing consumers to switch energy supplier through those platforms. This tools provide dashboards as well as tools for data analysis such as data charts elaboration, creation of customized dashboards, visualization of data from sensors and meters, etc.

Energy Communities favour the acceptance of energy efficiency actions, achieving a greater involvement of local citizens, institutions and companies. Citizen Energy Communities have as primary purpose providing environmental, economic and social community benefits. For that, they engage in generation, including from renewable sources, distribution, supply, consumption, aggregation, energy storage, energy efficiency services or charging services for electric vehicles. For empowering this engagement, tools like tokenization are used for rewarding those users who

actively participate.	
Relevance of EO in these technologies: EO might be able to reveal heat loss (e.g. of buildings) and lighting, though smart lighting would not depend on it	
Application sectors: Smart cities, smart grids, selft-consumption	**Keywords:** Engagement, communities, digital tools
Main stakeholders doing R&D: AECOM, Quicksand, iProximity, Zoniz, Agrupación Clúster de Electrodomésticos de Euskadi AIE	**Main stakeholders in the market:** Carrau Corporación Jurídica y Financiera S.L., Grupotec Tecnología Solar S.L. GT Energía, Sernoven S.L., Inversiones en Energía Solar S.L., Veolia, Solar Rocket, Robert Bosch, Electronics Trafic S.A., Ampere Power Energy, Quetzal Ingeniería, Azigrene Consultores, Cumulus City, Exclusivas Energéticas, ESS Bioconsulting, Atrae Foro de Energía

Energy efficiency technologies in municipal facilities: smart space buildings and efficiency in public lighting
Description of the new emerging technologies: Traditionally, energy savings has been a driver for building management globally. Gradually, energy benefits are becoming secondary to operational efficiency and non-energy benefits such as occupancy analytics, air quality and worker productivity. In this sense, **space utilization** is becoming the significant differential metric particularly in the commercial building market**. As** employees increasingly work from home, facilities-management corporates must come up with ways to address the shrinking workforce and growing oversupply of office space. As a result, **data-driven solutions** which can optimize the productivity metric have been gaining increasing momentum to address costly underutilized space. For example, **IoT sensors in combination with SaaS platforms** are helping to power dynamic workspace strategies, by identifying where employees are best situated to work at any specific moment. This space **sensing analytics**, developed by Vergesense, applied in the **HVAC market**, could allow the monitoring in order to identify if space should be heated, cooled, ventilated, etc. Another example of this type of technologies would be the **software application for heating and cooling** systems developed by Comfy. It allows creating a zone-level optimization of space conditioning and occupant control in commercial buildings, varying temperature based on space utilisation and allowing savings between 15-20% on energy bills. Last example would be ThoughtWire's **digital twins based on data from people, process and the physical built environment**, for hospital buildings digitalization. This tool enables the improvement of patient outcomes with a **data model** of a hospital's building systems, clinical and IT systems, IoT devices, workflows and people occupancy data. Regarding the adoption of **energy-efficient technologies** for street lighting, the use of **light-emitting diode (LED)** street lighting is one of the preferred options, offering reductions in the energy bills, improve lighting quality for public safety and meeting climate, environmental and efficiency goals. Another well-known option is **selling the light assets through buyback programs**, so the cities can invest in upgrades. Local governments recognize that street lights represent digital real estate that serves as a platform for new technologies and can help them evolve into smart cities. Dispersed throughout the city, street lights can also act as **data command posts** capable of gathering and conveying city data such as air quality, traffic and noise levels. Offering the infrastructure for these services could improve the revenue streams by providing **new services** as electric vehicle charging infrastructure dispersed throughout the city, wireless communication services, real-time video for monitoring traffic and weather, etc.

Relevance of EO in these technologies: Lighting detection	
Application sectors: Smart cities, smart grids, self-consumption	**Keywords:** Data-driven solutions, IoT sensors, digital twins, light-emitting diode, lighting
Main stakeholders doing R&D: Neolux, Lumenia, ATP, Siemens, Cleantech Group, L&T Technology Services, Exalto Energy & Innovation, Owens Corning and Cree Inc.	**Main stakeholders in the market:** Eléctricas Hermanos Campos S.L. Campos Eléctricas, Sernoven S.L., Veolia, Robert Bosch, Electronics Trafic S.A., Quetzal Ingeniería, Azigrene Consultores, Cumulus City, Generval, Schreder Socelec, ESS Bioconsulting, Eiffage Energía, Lyopro

Energy efficiency and technologies for the integration of renewable energies in municipal buildings and facilities	
Description of the new emerging technologies: Many studies have been carried out in the last decades looking for ways to effectively integrate renewables into envelopes of municipal buildings and facilities. In the case of historical buildings, most of these attempts are focused on **PV integration into building roof systems**. Existing buildings are **refurbished** to minimise energy consumption and trying to explore different methods for integrating renewable energy technologies. Once the building is equipped, then the building and heating and cooling demand can be provided by **renewable energy sources as biomass wood pellets, geothermal heating, solar thermal heating, etc**. Attempts to integrate **solar energy systems** into building components represent the most popular strategy, allowing a wide variety of possible integration solutions in roofs and facades. Pro-active collaboration with the local administration is a key step to explore other effective options, such as the **location of those renewables in alternative structures located in close proximities but not openly visible**. The integration of solar energy systems also focus on specific technologies, e.g. **new photovoltaic tiles, technologies less visually intrusive**. Also, PV panels are being designed to be effectively mitigated within the building roof layer colour and shape, with materials consciously selected. Other approaches apply **solar energy combining three functions, i.e. day-lighting, solar powered LED lighting and natural ventilation**.	
Relevance of EO in these technologies: Identification of possible allocations	
Application sectors: Energy efficiency, renewables energy, smart cities, self-consumption	**Keywords:** PV integration, renewable energy sources, less intrusive, lighting, ventilation, renewable, site selectin, inspection, maintenance, solar, photovoltaics
Main stakeholders doing R&D: Xcel Energy, Siemens, GE Energy, Avangrid Renewables, Iberdrola, Natcore, First Solar, Dunavnet	**Main stakeholders in the market:** IM2 Systems, Energy Investment and Consultancy S.L., Power Electronics España S.L., Alfa Desarrollo de Sistemas S.L., Carrau Corporación Jurídica y Financiera S.L., Grupotec Tecnología Solar S.L. GT Energía, Bornay Aerogeneradores S.L.U., Eléctricas Hermanos Campos S.L. Campos Eléctricas, Valfortec S.L., Heliotec 2006 S.L., Sernoven S.L., Inversiones en Energía Solar S.L., Veolia, Solar Rocket, Greendok, Ampere Power Energy, Quetzal Ingeniería, Indertec, Azigrene Consultores,

	Innergy, Generval, Gana Energía, Exclusivas Energéticas

Environment Sector

The opportunity to prevent global warming rising beyond 2C is diminishing – highlighting the urgent need for faster deployment of low carbon and climate adaptation solutions. Current efforts remain insufficient to change our course towards dangerous climate change. A rapidly warming climate and failure to adequately reduce greenhouse gas emissions underscore the urgent need for greater focus on resiliency measures. Rapid, large-scale investment in effective solutions is needed to prevent global warming from reaching potentially catastrophic levels.

Falling prices for both renewable energy and natural gas have resulted in modest emissions reductions amongst heavy emitters such as Europe and the United States. However, none of the four largest global polluters (China, the United States, the European Union and India) are currently on track to do their part in global efforts to reach the Paris Agreement goals.

Experts report that global greenhouse gas emissions rose by an estimated 2.7 percent in 2018, reaching an all-time high. This represents the second year of notable increases after a brief period of relatively stable emissions due to slowed economic growth. The latest IPCC report highlighted the severity of impacts we are already experiencing at 1C warming and stated that 2C of warming is now considered highly dangerous. Countries have agreed to report on their emissions every two years starting in 2024, in accordance with the new Paris Agreement rulebook agreed at COP24 in December 2018 in Poland.

International media focus continues to remain on emissions from electricity generation, where the greatest progress is being made. But agriculture and transportation are also major contributors and only limited attention is being given to these sectors and other smaller emitters. The European Union has struggled to maintain emissions reduction momentum, in large part due to Germany failing to transition away from coal. Meanwhile US carbon dioxide emissions rose by 3.4 percent in 2018, the biggest increase in eight years.

China continues to heavily invest in renewable energy, electric vehicles and energy storage, but its total emissions are predicted to continue climbing until 2030. India's emissions are anticipated to peak in 2033. Air pollution related to consumption of fossil fuels remains a major global issue. More than 3 billion people are breathing deadly smoke in their homes from using polluting stoves and fuels.

We expect to see billions of dollars of additional damage and many more lives lost due to extreme weather events. Resilience, adaptation and liability regarding infrastructure that is ill prepared for increasingly extreme weather will be front and center for both governments and business. Companies will accelerate action to increase climate preparedness in both direct operations and their supply chains. Geoengineering technologies could see greater investment from the private sector and renewed discussion at the policy level.

The expected impact of all the previous on business can be summarized as follows:
Prioritize investment in climate resilience and adaptation.
Companies need to increase the resilience of their supply chains and direct operations. This will require investment in climate risk assessments and scenario planning.
Shape policy and lobby governments for more climate action

Companies need to play a more active part in national and global efforts to implement the Paris Agreement and exert greater pressure on governments to limit global warming. This means advocating for actions like a price on carbon, aggressive deployment of renewables and electric vehicles, and climate smart agriculture solutions.
Increase Collaboration Efforts to Scale Low Carbon Economy Solutions
Rapidly reducing greenhouse gas emissions and increasing the resilience of infrastructure will only be achieved through multi-sector collaboration. Companies need to work with corporate peers, governments, NGOs and others to leverage the diverse skills required to scale low carbon economy solutions in all industries.

The following table briefly presents the results of a study regarding technological trends in the Environment sector. Hereinafter we examine the main technologies, focusing the watch in those technologies showing a possible relation to EO sector.

STAGE	SEGMENT	TECHNOLOGIES
CLIMATE, ATMOSPHERE, WEATHER	AIR QUALITY	Less polluting vehicles
		Pollution removal technologies
		Air quality monitoring technologies
	CLIMATE CHANGE	Emissions measuring technologies
		Industry digitalization
		Data collection technologies
		Data analysis technologies
		Carbon fixation technologies
		Waste valorisation technologies
		Renewable/compostable materials
LAND USE, LAND ECOSYSTEMS	FOREST	Biotechnology
		Nanocelulose extraction and
		Nanotechnology and nanomaterials
		Phytoremediation technology
	LAND MONITORING	ICTs
		Laser measurement for precision forest inventory and monitoring
		Geographic Information Systems (GIS)
		Remote sensing
MARINE ECOSYSTEM		Ocean planning technologies

Climate, atmosphere and meteorology

Air quality

There is a growing sense of urgency about the need to clean up air pollution. For this aim, there exist many key technologies to tackle air pollution, including lower emission vehicles (including electric, hybrid and LPG), car sharing and lower emission sources of heat and power. Whilst the role of these technologies in reducing air pollution is generally accepted, there are also numerous other emerging technologies that could also be interesting such as air quality monitoring and pollution removal technologies.

Less polluting vehicles	
Description of the new emerging technologies: It is the case of **gas to liquids**, for example, switching to alternative fuels. Electric and LPG offer separate fuel systems, but there are other options offering the potential to clean up the existing diesels. One example is the new synthetic gas to liquid (GTL) fuel developed by Shell, derived from natural gas. The use of GTL in heavy duty vehicles has proved to reduce the NOx emissions by 5-37%. Another example is the natural gas converted into dimethyl ether (DME), able to reduce NOx emissions by around 25%. DME is less straightforward to implement than GTL in the sense that it requires some engine modification. In any case, manufacturers such as Ford and Volvo are investigating the potential to bring DME fuelled vehicles into the market. The use of **hydrogen fuel additives** can also allow reductions in emissions. For example, CGON developed a technology that fed small amounts of hydrogen into the vehicle air intake such that it creates a more efficient burn, increasing fuel efficiency and reducing emissions. New technologies are also being developed to address very specific sources of pollution. For example, a growing source of pollution in cities comes from refrigerated vans and trucks. Whilst trucks are subject to emissions standards, the auxiliary engines used to power refrigeration units are largely unregulated and are highly polluting. Technological company Dearman is developing an alternative system based on the use of **liquid air**, which produces zero emissions on the road.	
Relevance of EO in these technologies: Detection of resources, pipeline monitoring, monitoring of production facilities	
Application sectors: Sustainable transportation, human health, automotive, society	**Keywords:** Gas-to-liquids, hydrogen fuel additives, liquid air
Main stakeholders doing R&D: Shell Global, Compact GTL, CGON, Air Liquide	**Main stakeholders in the market:** Shell Global, Compact GTL, CGON, Air Liquide

Pollution removal technologies	
Description: An alternative to cleaning up emissions from vehicles directly could be to deploy **technologies which remove pollution from the ambient air**. For example, a number of companies are developing **photo-catalytic treatments** which remove pollutants from the air in the presence of sunlight. These treatments can be applied to a range of surfaces, for example roofing tiles, roofing felt or even the surface or roads. Similarly, developers are also looking at other ways of cleaning air in urban environments. Studio Roosegarde, a Dutch design company, has developed a smog free tower consisting of an **air purifying tower** which sucks in pollution and expels clean air. The extracted pollution is, somewhat bizarrely, turned into pieces of jewellery. Other examples of air purification technologies include the air purifying billboards and pavement and vertical forests. Although many cities like the space for large green areas in their downtown core, building forests vertically along with skyscrapers, has become a very interesting development to filter pollutants from the air. Some cases have been already developed by the Italian architect Stefano Boeri.	
Relevance of EO in these technologies: Air quality detection	
Application sectors: Society, Human Health, Construction, Materials	**Keywords:** Photo-catalytic treatments, new designs, air purifying, air quality
Main stakeholders doing R&D:	**Main stakeholders in the market:**

Dürr, Co2 Solutions, Shell, Chevron, NRG Energy, Carbon Engineering, ClimateWorks	Dürr, Co2 Solutions, Shell, Chevron, NRG Energy, Carbon Engineering, ClimateWorks

Air quality monitoring technologies	
Description: The growth of the urban air pollution is one of the most serious indicators of the impact of global urbanization on the environment and human health. The rapid urbanization, with the associated economic and population growth, has led to increases in vehicles use, industrial activity and energy consumption that have raised urban air pollution to critical levels, according to the data from the World Health Organization (WHO). To fully understand and improved air quality conditions, pollutants must be accurately measured, monitored and managed. Currently, most cities monitor the quality of the air using a **collection of large environmental monitoring stations**. In this sense, recent advances in **sensor and communication technologies** have led to smaller, cheaper and more localized monitoring solutions. This use of lower cost sensor nodes with **wireless communication systems** is filling the gaps left by legacy environmental monitoring stations. As supplement to traditional measurement stations, there are the **sensors networks**, for example, the **air quality Internet of Things** network deployed in Helsinki (Finland), installed alongside existing air pollution monitoring stations. Networks allow the generation of new **air quality maps, predictive air quality models and open data** and the provision of information to residents of at-risk areas. Sensor networks are also evolving to mobile solutions. For example, some projects work on the attachment of sensors to moving object such as cars and vans looking to provide insight on how air quality differs from street to street within cities.	
Relevance of EO in these technologies: Air quality detection	
Application sectors: Society, Human Health, Cities, Environmental technology	**Keywords:** Environmental monitoring stations, sensors network, wireless communication, air quality maps, predictive models, open data
Main stakeholders doing R&D: BreezoMeter, Libelium, eLichens, Green City Solutions	**Main stakeholders in the market:** BreezoMeter, Libelium, eLichens, Green City Solutions

Climate change

In many cases people will adapt to climate change simply by changing their behaviour, but often they will employ different forms of technology, whether hard forms such as new irrigation systems or soft technologies such as crop rotation patterns. Nevertheless, as with any form of technology, there is always the risk that adaptation measures will be more accessible to wealthier communities. Some of the identified technologies related to climate change are presented below, all of them showing a possible relation to EO data.

Emissions measuring technologies
Description: The first step in design strategies for adaptation is to collect information. There are multiple methods of data collection, including many types of equipment, from **tidal gauges** to **satellite remote sensors**. There are also more ways of analysing and presenting this data using **sophisticated computer graphics programs**, known as **geographic information systems (GIS)**.

Technological innovation gives ways to solve environmental challenges. An example could be the **new approaches to measuring and reducing emissions** of methane, which are responsible for a quarter of all the warming the environment is experiencing today. Researchers use a range of technologies, including **sensors mounted on drones, airplanes and even Google Street View cars**, to measure emissions every link in the supply chain. Through reliable, low-cost sensors, remote monitoring and oilfield internet-of-things, energy companies could reduce their emissions and eliminate waste of saleable gas at the same time. In this sense, companies such as Shell and Equinor are testing **continuous monitoring technologies**, and others such as Stanford University and ExxonMobil look at **mobile detection technologies** to be used in aircraft and drones. **Advanced sensor technologies** help creating a healthier environment, for example Google cars mapping air pollution and its health effects or the wearable bracelets designed to track the daily chemical exposure. Elsewhere, retailers and consumer brands are using **blockchain technologies** to improve accountability and sustainability across extensive supply chains. For example, sensors are used to help farmers reduce the amount of chemicals on their fields. Pushing the envelope even further, emissions could be also detected and measured by means of **satellite-based approaches** that can continuously map and measure emissions with exacting precision almost anywhere in the planet.
Relevance of EO in these technologies: Air quality, gas leak detection

Application sectors: Society, Human Health, Cities, Environmental technology	**Keywords:** Remote sensors, geographic information systems, advanced sensors, mobile detection, continuous, blockchain, satellite-based, air quality
Main stakeholders doing R&D: Shell, Equinor, ExxonMobil	**Main stakeholders in the market:** Shell, Equinor, ExxonMobil

Industry digitalization
Description: The ever-expanding platform of **mobile connectivity**, together with the emergence of **5G-enabled cyber-physical systems** and **advanced cellular IoT**, are laying the foundation for the fourth industrial revolution that will transform the existing business structures and provide a basis for disruptive new business. **Industry 4.0** arrives in time in a critical moment for climate action. IoT, as an enabling technology, will drive an increase in industrial efficiency and help to better measure the climate impact. Digital technologies are supposed to be capable of accelerating the reduction of global emissions by up to 15% by 2030. The era of digitalization brings key technologies for achieving and energy-efficient industry. It is the case of **wireless IoT with Augmented Reality (AR)** and **machine learning**, allowing an increase in the overall efficiency and quality in manufacturing. Sustainability impact analyses show overall reductions not only in energy consumption, but also in transportation related pollution and the use of natural resources. Better **connectivity with 5G** will make the onboarding of IoT much easier, making industries more measurable, trackable and smarter in decisions executing. Other potential technology is related to the application of remote experts that used augmented reality technologies to troubleshoot and communicate remotely with on-site technicians. Moreover, wireless IoT also allows the regulation of the temperature on the factory floor,

resulting in reduced Cow emissions and up to 2'% lower heating costs. As production increases, warehousing hubs continue to grow in numbers. Autonomous Electric Transportation powered by 5G can be a key enabler in reducing transport emissions.	
Relevance of EO in these technologies: Network design optimisation	
Application sectors: Society, Industry 4.0, Transport equipment manufacturing, Mechanical and electrical engineering	**Keywords:** Mobile connectivity, cyber-physical systems and advanced cellular IoT, Industry 4.0, wireless IoT, Augmente Reality, machine learning, 5G
Main stakeholders doing R&D: Siemens, Accenture, PwC, McKinsey, **Altran**, Alten, Demcon, Festa Solutions, Beltech, Petrofac, Airbus, Amazon	**Main stakeholders in the market:** Siemens, Accenture, PwC, McKinsey, **Altran**, Alten, Demcon, Festa Solutions, Beltech

Data collection and analysis technologies	
Description: The significant increase in scientific data that occurred in the past decade -- such as NASA's archive growth from some hundred Terabytes in 2000 to 32 Petabytes of climate observation data, as well as ECMWF's climate archive of 220 Petabytes-- marked a change in the workflow of researchers and programmers. Largely the data responsible for this development is multidimensional arrays (or data cubes), and is foundational in Earth / Life / Space sciences, as well as industrial sectors like agriculture, mineral resource exploitation etc. The datacube paradigm has proven instrumental in making spatio-temporal Big Data analysis-ready, thereby easing access for experts and non-experts alike. Pioneered by the rasdaman technology, meantime a range of prototypes has emerged. Implementation techniques vary: while rasdaman is a full-stack C++ implementation many tools add an extra layer on top of some existing library, often in python. **Array databases aim** to provide flexible, scalable services on exactly such massive datacubes. Of the currently available implementations, rasdaman is particularly relevant to EO as it is supporting several open OGC datacube standards (WCS, WCPS, WMS), and is in operational use at research institutions like AWI and HZG, smart farming startups like EOfarm and CropMaps, and on Petascale data centers like DIASs and CODE-DE. The **Internet of Things, cloud computing, big data** tools to investigate climate, as well as **intelligent analytics** platforms and new technological progressions, have further emphasized the need for big data analytics support in climate science and big data science. Given the context of combating climate change, existing research has applied big data analytics in mainly the aspects of energy efficiency, intelligent agriculture, smart urban planning, weather forecast, natural disaster management, etc.	
Relevance of EO in these technologies: Essential	
Application sectors: Telecommunications services, computer science	**Keywords:** Cloud computing, in memory processing, real-time processing, big data analytics, IoT, intelligent analytics, datacubes, multidimensional arrays
Main stakeholders doing R&D: Google, Microsoft, Long Live the Kings, JJAIBOT, Dymaxion Labs, DHL, IBM, 50 Reefs, rasdaman	**Main stakeholders in the market:** Google, Microsoft, Long Live the Kings, JJAIBOT, Dymaxion Labs, DHL, IBM, 50 Reefs, rasdaman

Waste valorisation technologies	
Description: Closing the loop of product lifecycles through greater recycling and re-use or resources can bring benefits for both the environment and the economy. It is the case, for example of recycled nutrients from organic waste or by-products (bio-based materials such as food waste, used water and animal by-products such as manure) that can be returned to the soil as fertilisers, reducing the need for mineral-based fertilisers and creating organic fertilisers for farmers and gardeners. Another case is the waste conversion technology called **Thermo-Catalytic Reforming** that converts residual biomass into three main products: biochar (containing phosphorus and potassium), hydrogen-rich synthesis gas, and liquid bio-oil that can be refined into high-grade bio-fuels. Universities are by far the most active organizations in biowaste valorisation. For example Ghen Univeristy worked on a project to create agri and food waste valorisation co-ops based on flexible **multi-feedstocks biorefinery processing technologies** for new high added value applications. The Agricultural University of Athens, on the other hand, research in agro-industrial waste utilization using oleaginous yeast for the production of biodiesel. There also exist active organization innovating in biowaste valorisation . For example, Lystek International commission to demonstrate that source separated food waste, and potentially other organic waste streams, can be pre-treated and processed to produce a high-quality biogas, which can ultimately be used as a fuel source for electrical energy generation. Also ThyssenKrupp has a patent application on a modified propane dehydrogenation system for producing chemical products and are also developing for recycling low-grade suplhidic mining waste for critical-metal, mineral and construction raw-material production in a circular economy.	
Relevance of EO in these technologies: Applicable for site selection	
Application sectors: Waste management, waste treatment	**Keywords:** Thermo-Catalytic Reforming, multi-feedstocks biorefinery, biowaste valorisation, circular economy, Smart Cities
Main stakeholders doing R&D: Tecnalia, AIMPLAS, ITENE, IRIS, OWS	**Main stakeholders in the market:** Tecnalia, AIMPLAS, ITENE, IRIS, OWS

Renewable/compostable materials
Description: With consumer concern regarding plastic waste, fashion brands are attempting to reduce their environmental impact by moving to alternative materials. Mainstream fashion and beauty brands work to eliminate consumer packaging altogether in the quest to reduce their impact, and as only 9% of plastics are currently recycled, removing all but the most essential packaging seems the most sustainable approach. **Compostable packaging** solutions still present sustainability challenges as the infrastructure needed to effectively collect and compost the items at scale is not established in most places in the world. In some cases where the packaging is directly being erased. It is the case of Lush, where employees use an app using artificial intelligence and product recognition software to scan items to find out more about their products. Others, like in the case of the joint venture Paboco, look for new packaging solutions, partly renewable and fully recyclable.

New innovative materials substitute single-use plastic solutions, and most of them can be recycled in domestic recycling schemes. For example, Burberry has launched a new line of packaging including paper packaging made from FSC certified virgin pulp and 40% recycled coffee cups, which can be recycled in domestic household recycling schemes. Another example is the ocean plastic bottles developed by Ren, who in partnership with leading recycling organisation Terracycle, launched a recycled and recyclable plastic bottle containing 20% ocean plastic. **Alternative bio-based** options also include cassava starch garment bags developed by Complast and used, for example, by sustainable-designer-of-the-moment Maggie Marlyin. Noissue packaging supplier is also working in the creation of customisable compostable mailers which are made from corn-based bio-polymers (PBAT and PLA) certified for in-home and industrial composting. Other example of new materials is the case of Finisterre brand, the first fashion brand to use garment bags made from the Aquapak polymer, Hydropol. The polymer is oil based, however, it is engineered to dissolve in water or break down in anaerobic conditions to leave carbon dioxide, water and biomass.	
Relevance of EO in these technologies: Localization of bio sourced oil, plastic, gas	
Application sectors: Packaging, bio-materials, renewable materials	**Keywords:** Compostable packaging, recycled materials, bio-based alternatives
Main stakeholders doing R&D: Agilyx, Bioplastech, TIPA, Recycling Technologies, Pond Biomaterials	**Main stakeholders in the market:** Agilyx, Bioplastech, TIPA, Recycling Technologies, Pond Biomaterials

Land use and land ecosystems

Forest technologies

Technology has been relied on in the quest for sustainable forestry. Biotechnology has been used for the genetic improvement of forests and plant cloning, while biomass conversion technologies have been used to turn biomass into energy. However, its impact on the forestry sector still has not been fully investigated, probably because forest researchers are not so tech-savvy.

Within these technologies, the **Geographic Information System** can be found, a computer system used for mapping and doing geographical analysis by capturing and displaying data related to positions on Earth's surface. It can make use of any information containing location, improving the process of decision-making as well as communication, so it is widely used across multiple industries. In the case of the forestry sector, the data collected can help to discover the location of endangered species and habitat classification, the size of the forest area and the forest cover type. Datacube systems (e.g. rasdaman) add time-series analytics capabilities to traditional GIS systems, enabling change detection, simulations and forecasting.

Nanotechnology has also been increasingly used in the forestry sector to improve its products and make them more competitive to the market. There have been attempts to use a wood-based nanomaterial to produce clear reinforced glass with the hope to reduce greenhouse gas emissions. Another example is the extraction of cellulose, a biosynthetic product from plants, animals and bacteria. Nanocellulose refers to cellulosic materials with defined nano-scale structure dimensions, used in many applications in thermo-reversible and tenable hydrogels, paper making, coating additives, food packaging, etc.

Furthermore, **phytoremediation** implies the use of woody plants to clean the environment by decontaminating it. In this approach, plants are used to accumulate toxic metals and organic pollutants from contaminated soils and waters for clean-up purposes, being less invasive than traditional methods as landfilling. The most commonly used forms of phytoremediation are phytoextraction, which removes toxic metals by accumulating them in the biomass of plants, and phytodegration, which uses plants to degrade the pollutants.

Also **remote sensing technologies** are being used in the forestry sector. Different devices and approaches such as synthetic aperture radar, aerial photography or satellite images are able to measure objects by use of a photogram without touching them, providing much more detailed images. Their efficiency and scope can be improved when combined with Geographic Information Systems and GPS data.

Regarding the **ICT development** for the global forest sector, the demand for graphics paper products will be lower than it would be without the ICT development. The impact will be of major significance. Paper consumption will be reduced, having negative impacts to the prices and profits. Pulp and paper industry companies would be not only competing against other paper companies, but also against the electronic media. However, at the same time, ICT can help to boost productivity and creation of new products. The convergence of print and electronic media is also creating new products, such as radio-frequency identification (RDIF) tags and intelligent packaging products.

Biotechnology has also many applications in the environment. Plants can be multiplied by clonal propagation, giving identical offspring. Gene transfer of valuable genes has been conducted for the genetic improvement of forests. The challenge is to get products that are ecologically friendly and that will function well in changing environmental circumstances. Fast–growing plantations permitting lower costs, higher product quality and reduced use of both chemicals and energy are needed, and biotechnology has significant potential to help the forest products industry overcoming these challenges. For example, through clonal propagation, large numbers of genetically identical plants can be produced. Techniques such as somatic embryogenesis have several advantages over other propagation systems, including high multiplication rates and the potential for scaling-up and delivering via bioreactor and synthetic seed technologies.

Precision Forestry is achieved through **Advanced Laser Measurements**. The most fundamental contribution these bring is to provide means to more accurately, more objectively and more efficiently measure and monitor the quantity and quality of the forest biomass. Precision forestry can then be used to increase the efficiency and information basis of existing national forest inventories and operational forest management planning. It also allows certification of wood origin, since the location of every stem is recorded by forest inventory and logging machines, and up-dated to maps. This more detailed information on forest resources also brings new points of view to forest science and can be utilised in more detailed development of models to be applied in analysis of scenarios of global climate change studies.

In spite of consisting of potential innovations, the described forest technologies do not present a direct possible relation to EO data.

Land monitoring

Land Administration and Mapping are significant domains of activity, consistently growing worldwide and evolving continuously for the sustainable benefits of citizen, state and business.

Geo-information has long been a necessary data source for mapping and it continues to play a crucial role in supporting key decision-makers by turning the latest geospatial data into reliable information. Some examples of technologies/applications related to land monitoring are shown below. More and more they are implemented through continuous automated analysis of remote-sensing EO data, often utilising a datacube server such as rasdaman.

- Inland water monitoring– Sentinel 2 and 3, combined with in situ data for calibration and validation, allow to assess the temporal and special water quality dynamics. Historical data enable modelling to forecast water quality.
- Monitoring of snow
- Monitoring of the land change and biodiversity
- Land use – illegal activities, assessment of human activities on land
- Topography
- Built environment – monitor the urban areas and surroundings, mapping and monitoring of the infrastructure
- Monitoring crops and farming practices
- Monitoring natural hazards (drought, flood, forest fires)
- Monitoring desertification and soil productivity
- Monitoring natural succession processes
- Monitoring protected areas

Marine ecosystems

Maritime Surveillance has become a huge challenge over the past few decades, specifically in regions where maritime traffic represents the major economic interest, potential threats or source of illegal activities such as smuggling, illegal immigration or piracy.

The great maritime nations consider that they do not have the capacity to monitor the entire Exclusive Economic Zone (EEZ) using only traditional means. Satellites extend surveillance capacities from coastal areas to open seas and provide information in order to optimise operations at sea.

Examples of marine resources technologies are:

- Ocean quality and productivity – monitoring of pollution (water quality)
- Monitoring marine habitat
- Coastal management
- Metocean – meteorology of ocean (current, wind, waves, etc.) – impact on the shipping
- Fishery – illegal fishing, map fish shoals
- Monitoring and detection of ship
- Ice monitoring on the sea

Ocean planning technologies
Description: Lot of potential can be seen in **Artificial intelligence** (AI), specially for fisheries and electronic monitoring. There's been a lot of research into **computer vision** for enumerating catch. This makes it possible to create and use **classifiers** (algorithms that automate categorization of input) that can drastically reduce the amount of time it takes to review video from electric monitoring systems. Technologies that only require a web browser have tremendous potential to improve ocean

planning. For example, for geospatial analysis, this is the case of Esri's Geoplanner (and other similar apps such as SeaSketch) that have tremendous potential to improve ocean planning, management, and ultimately ecosystem health because they provide geospatial analysis directly within a web browser (i.e., not just *viewing* of data or maps but actual use of geoprocessing tools). GeoPlanner includes dozens of powerful **geoprocessing tools** that are much easier to access, run, and understand than those within the more complex world of the desktop tools. They also run much more quickly and are shareable with others almost instantaneously allowing for faster decision-making.

On large ocean-related EO data (Sentinel 1/2/3, Chlorophyll Color, Sea Ice Concentration, etc), datacube systems provide a suitable solution for doing effective ocean planning. Rasdaman is already in operational use at marine research institutes AWI and HZG, which together form the beginning of a larger planned European marine datacube federation.

Remote camera systems are also being used for ocean planning. For example, in South Africa, **remotely operated vehicles** (ROVs) and tow cameras are being used to support ecosystem classification and mapping, identify and propose protection for sensitive habitats, monitor threatened species, and understand human impacts in the ocean.

Regarding the maritime industry in terms of maritime supply, over the next years, it will increasingly adopt solutions to address security and overcapacity. New digitization solutions, such as **big data, blockchain, automation, drones, and robotics**, are enabling the maritime freight industry to introduce game-changing approaches that will significantly reduce or eliminate non-value-added activities.

Relevance of EO in these technologies:
Highly relevant. Sea i.e. detection, illegal fishing, dark vessel detection, oil spill detection, metocean, water quality, infrastructure site selection, infrastructure monitoring/inspection/maintenance

Application sectors: Aquaculture, Fishing, Existence of biodiversity	**Keywords:** Artificial Intelligence, computer vision, classifiers, geoprocessing tools, remote camera systems, remotey operated vehicles, bid data, blockchain, automation, drones, robotics
Main stakeholders doing R&D: Advisian, MetOcean Telematics, MetOcean Telematics, Pro-Oceanus Systems Inc.	**Main stakeholders in the market:** Ocean Sonics, Irving Shipbuilding Inc., AML Oceanographic, Realtime Aquaculture

Food Sector

In recent years, food has gained increased importance in the society we live in. On one hand, nutrition and health have become an important aspect for people when selecting everyday meals.

Simultaneously, the availability of different foods and ingredients has opened up doors to new cousines, tastes and flavours and created a movement of people interested in exploring what this field has to offer. In this way, food is no longer just a means to satisfy hunger, but has also become a medium for exploring new cultures, cousines, traditional recipes with modern twists, meeting people and exchanging experiences. Yet, with the rising need to feed a growing population in the face of climate change and environmental degradation, food plays a key role in building a sustainable future.

In this complex landscape of challenges and potential, the farm-to-fork value chain arises as a field where innovation is essential as a way to meet the future ahead. While agriculture still is the least digitized of all major industries, we constantly witness new technological advancements in the sector. With the value chain surrounding the food sector spanning a range of areas from seed monitoring and farming to retail and restaurant business, this section gives an outlook in the newest technological advancement across the whole value chain. While information in this section was compiled through a comprehensive desk research and analysis of multiple sources, one of the most important sources has been AgFunder and its reviews of the newest technology trends.

Technology's increasing role is notable in different industries including food and agriculture. With agrifood being "a $7.8 trillion industry, responsible for feeding the planet and employing well over 40% of the global population" the potential technology has on increasing the productivity of the sector must not be neglected. In the face of global challenges imposed by climate change, population increase, environmental degradation and others, technology solutions in the agrifood sector address a broad range of challenges such as labor shortages, food safety and traceability, farm efficiency and profitability, drought, CO_2 emissions, food waste, health and sugar consumption, unsustainable meat production etc.

Field-Phenotyping (HTPP) Techniques for plant breeding
Description: The main goal of phenotyping in plant breeding is to identify plants with improved traits and presents differences based on the crop, trait, developmental stages and the resources available. Development of phenotyping tools and methods for both proximal and remote sensing accelerates screening and selection of germplasm. **High-Throughput Field-Phenotyping (HTPP) Techniques** can enable screening of larger number of samples with higher accuracy and reduced costs, thereby improving the selection intensity and accuracy. HTPP can also enable evaluation of traits that are otherwise invisible to the naked eye or are correlated with the trait of interest. This broadens the genetic variation in the breeding material as germplasm with such traits could then be retained in the breeding programs. Satellite imaging is readily available with multispectral spatial resolution ranging from 1.24 m to 250 m. The major limitations with satellite imaging are the weather conditions, frequency of imaging, resolution, costs for imaging and the time it takes from image acquisition to access. Data from medium resolution satellites are freely available while the data from the high-resolution satellite is available commercially. As plant breeding trials usually consist of small sized plots, higher resolution satellite images are necessary. Plant breeding programs often evaluate thousands of genotypes in small plots of approximately one square meter in size in early cycles of selection. Such plots are not possible to evaluate even with the most advanced satellite sensors (WorldView-3). Thus, for plant breeding trials, satellite imaging is useful for evaluation of moderate to large sized trial plots while for smaller plots, aerial imaging with **unmanned aerial vehicles** (**UAVs**) and proximal phenotyping with **handheld sensors** for estimating plant chlorophyll fluorescence, canopy temperature, nitrogen content, leaf area and plant height, are viable alternatives. As yield trials are done at later generations of selections and are often performed with larger plot sizes of several meters in width and length, satellite imaging could be a viable alternative

for evaluating yield trials in plant breeding. Such yield trials are often replicated at several locations to study genotype by environment interactions. **Satellite imaging with medium resolution** (**Sentinel 2** and **Landsat 8**) could be especially valuable for such trials as these locations are often spread out across the country making it more laborious to perform proximal or drone-based measurements. Thus, considering the continuous reduction in costs for satellite imaging, greater demands for satellite imaging in plant breeding can be expected to be in evaluation of multi-location yield trials.	
Relevance of these technologies in EO: Copernicus satellite Sentinel-2: Level-1c product is an orthoimage product with pixel radiometric values provided in Top-Of-Atmosphere (TOA) reflectance. The product consists of 12 spectral bands with 10 m, 20 m and 60 m spatial resolution. Temporal resolution is less than 5 days with 2 operational satellites. NASA'S Operational Land Imager (OLI) Landsat-8 satellite consists of nine spectral bands with a spatial resolution of 30 meters for Bands 1 to 7 and 9.	
Application sectors: Plant breeding and selection, crop monitoring for plant health evaluation and stress detection, fertilizer requirement and weed detection in farming.	**Keywords:** Artificial Intelligence, drones, field phenotyping, precision breeding, precision agriculture, decision support systems.
Main stakeholders doing R&D: MyAgroApp, Agrivi, TalkingFields, FieldView	**Main stakeholders in the market:** AgroApps, OneSoil, FarmersEdge, Terranis

Pre- harvest sustainability indicators monitoring

Description:

A great challenge faced by global economy today is to integrate environmental sustainability with economic growth and welfare without compromising the ability of future generations to meet their own needs. Adopting sustainable production and consumption maximise business' potential to transform environmental challenges into economic opportunities and provide a better deal for consumers. This challenge is also important for the AgriFood sector, and especially the AgriFood companies, to improve the overall environmental performance of products throughout their life-cycle, to boost the demand for better products and to address consumers' needs for more sustainable choices. AgriFood companies under the contract farming business model, require detailed information on the practises followed to achieve production and the potential misuse of farming inputs. This information is exploited in an effort to continuously update and redesign the final products conformation with the quality and sustainability standards that have been defined under the contract agreement.

Artificial Intelligence (AI) techniques and Earth Observation (EO) technology coupled with innovative ICT can be used to develop and validate the services that are required for estimating sustainability indicators. The aim of these indicators is to cover the following **pre-harvest sustainability intentions**: i) Nature and biodiversity are protected and maintained; ii) Crop Protective Products (CPPs) are applied without harming the environment; iii) Water availability and quality are protected; and iv) Greenhouse gas (GHG) emissions are reduced.

i) Nature and biodiversity are protected and maintained. This intention can be addressed by ensuring compliance of suppliers with national legal obligations with respect to biodiversity. In order for the companies to evaluate the farmers' commitment to maintaining, as well as, enhancing the farmland's sustainability a spatial component is provided depicting several EO layers showing areas either unsuitable for farming or parts of the landscape of high biodiversity importance. In that way, expansion of agricultural areas (possible new contracts) or intensive agriculture operations can be controlled by the companies' Sustainability Advisers and adjusted in respect to biodiversity.

ii) CPPs are applied without harming the environment. This intention is addressed by producing high risk area maps and possible outbreaks warnings with the use of biotic enemies' development models. The models use as input the soil moisture content and high-resolution current and mid-term meteorological data to predict possible pest and disease attacks. The processing of the information by the companies is intended to highlight areas of possible CPPs misuse. Quality controls can be targeted both on final products, as well as through in-situ samplings to quantify possible CPPs residues that exceed thresholds and imply deviation from sustainable practices. **iii) Water availability and quality are protected.** This is addressed by ensuring compliance of farmers with national legal obligations with respect to water abstractions. Companies must ensure that suppliers follow regulations that typically apply to irrigation water use and abstraction. The total amount of water used by farmers to irrigate crops can be estimated using remote sensing data. In this way, excess exploitation and deterioration of water bodies, groundwater and aquatic ecosystems can be controlled by the companies and adjusted in respect to biodiversity. **iv) Greenhouse gas (GHG) emissions are reduced.** Tillage is the most energy-consuming field operation. It can account for more than 50% of the total fuel consumption during a growing season. If a tillage operation is performed under diverse soil moisture conditions, the fuel consumption increases dramatically and consequently GHG emissions. The soil workability conditions in parcel and sub-parcel level can be determined, and the timing of cultivation practices (tillage and harvest) can be detected through EO data. This information can be combined with the soil workability conditions these operations were performed and yield results on whether these are unsustainably performed and contribute to GHG emissions.	
Relevance of these technologies in EO: Copernicus satellite Sentinel-2: Level-1c product is an orthoimage product with pixel radiometric values provided in Top-Of-Atmosphere (TOA) reflectance. The product consists of 12 spectral bands with 10 m, 20 m and 60 m spatial resolution. Temporal resolution is less than 5 days with 2 operational satellites. NASA'S Operational Land Imager (OLI) Landsat-8 satellite consists of nine spectral bands with a spatial resolution of 30 meters for Bands 1 to 7 and 9. Sentinel-1: Level 1 C-band Synthetic Aperture Radar (SAR) Ground Range Detected product in High Spatial Resolution (HR) with 5x20 m pixel spacing and with temporal resolution between 2-3 days over Europe with 2 operational satellites.	
Application sectors: Modern agri-food supply chains (pre-harvest and post-harvest management), agri-food industries sourcing under the contract farming business scheme.	**Keywords:** Artificial Intelligence, drones, precision agriculture, decision support systems, sustainability indicators, machine learning, satellite data, EO techniques, pre-harvest management
Main stakeholders doing R&D: In most cases, this monitoring process is under the responsibility of the Sustainability Advisers, assigned by the companies.	**Main stakeholders in the market:** Companies wanting to comply to sustainability criteria assign to the Advisors the collection of data to address and evaluate the sustainability indicators by calculating the footprints.

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