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Space assets, technology and services in support of energy policy☆

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ABSTRACT

Space can be used as a tool by decision and policy makers in developing, implementing and monitoring various policy areas including resource management, environment, transport, security and energy. This paper focuses on the role of space for the energy policy. Firstly, the paper summarizes the European Union's (EU) main objectives in energy policy enclosed in the **Energy Strategy** 2020–2030–2050 and demonstrates how space assets can contribute to achieving those objectives. Secondly, the paper addresses how the European Space Agency (**ESA)** has established multiple **initiatives** and **programs** that directly finance the development of space assets, technology and applications that deliver services in support of the EU energy policy and sector. These efforts should be continued and strengthened in order to overcome identified technological challenges. The use of space assets, technology and applications, can help achieve the energy policy objectives for the next decades.

1. Introduction: the european energy sector

Europe has been facing problems related to energy supply. In particular, it faces strong dependency on imports from third countries, instabilities in oil and gas supply, and volatile energy prices. Additionally, the energy market faces a number of challenges in relation to the interconnection of national and international markets and the need for more transparency and European integration as well as the large investments related to energy infrastructure, transport issues, slow – albeit increasing – development of improved efficiency and renewable energy resources and the increased challenges posed by the global increase of energy demand and by climate change.

Space can be used as a tool by decision and policy makers in developing, implementing and monitoring various policies, amongst them energy policy [1]. The European Union is the world's largest regional energy market and the world's second largest energy market. Energy is a core element to industry, economy and the citizens and it is essential to ensure safe, secure, sustainable and affordable access to energy. The Union's import dependency in all fuels was 53.2% in 2013 [2]. The 2013 EU-28 energy gross inland consumption was 31.1% dependent on petroleum products, 21.4% on gas, 29% on solid fuels, 4.8% on nuclear and 13.5% on renewable sources [2]. Europe's import dependency for crude oil and gas is mainly from Russia (33.4% for oil and 39% for gas) and Norway (11.7% for oil and 29.5% for gas). Other sources for oil are Nigeria (8.1%) and Saudi Arabia (8.6%) and for gas Algeria (12.8%) and Qatar (6.7%) [2].

Europe perceived the risk of its dependence on energy supply during the 1973 Arab oil embargo. This highlighted three main issues [3]. First, the need for energy policy collaboration between the European countries and the producing world became evident. Second, necessary institutional mechanisms were needed to increase coordination for supply distribution. Third, Europe needed to prepare mechanisms to prevent becoming a possible victim of exporting countries who use energy supply as a political and economic weapon. This geared up the development of a common energy policy in Europe which had developed at a very slow pace. Europe also felt the energy disputes between the Ukraine and Russia in 2005–2006, when four-day energy cuts aimed at the Ukraine affected Europe. Since then, a variety of efforts have been made in Europe to enhance and speed up a European Energy policy. This energy insecurity was recently repeated in 2008–2009 when gas supplies to Ukraine were suspended and fifteen Member States were affected. This reminded the Union of its energy dependency and the need for a common voice and approach vis-à-vis the international communities and in particular when dealing with countries that are suppliers of energy products. The EU's key energy partners are Russia, Norway, U.S., India, China, Central-Eastern European Countries and OPEC countries (Algeria, Angola, Ecuador, Iran, Iraq, Kuwait, Libya, Nigeria, Qatar, Saudi Arabia, United Arab Emirates and Venezuela).

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2. The European energy policy and space as a tool in support of energy policy

The EU Energy policy finds its root in the European Treaty establishing the European Coal and Steel Community (ECSC) in 1951 aiming to create a common market for steel and coal. The second was the Treaty of Rome establishing the European Atomic Energy Community (EAEC), known as Euratom, in 1957 aimed at creating a common market for equitable supply of ores and nuclear fuels (source materials and special fissile materials), coordinating Member States research programs and drawing up of safety standards for the peaceful uses of nuclear energy.

Since 2006 Europe has been calling for a more comprehensive energy policy based on solidarity between the Member States. The 2006 Green Paper of the Commission defined a European energy policy with three main objectives aimed at attaining sustainable development. These are giving consumers competitive energy prices by increasing competition in energy markets, security of supply, and sustainability by reducing the energy system's environmental impact to acceptable levels and combat climate change [4,5]. Six key areas were identified where action is necessary to address the challenges of the need to develop a new, common European strategy for energy, with sustainability, competitiveness and security underpinning the strategy. These are:

- competitiveness and the internal energy market
- diversification of the energy mix
- solidarity
- sustainable development
- innovation and technology
- external policy [6].

The 2007 European Commission Communication *"An Energy Policy for Europe"* [6], sets out an Action Plan revolving around the two axes of the energy policy, the functioning of the internal energy market and the security of energy resources. In March 2007 during the EU Summit, the European Commission adopted the Energy Policy for Europe (EPE) pursuing the following three objectives, fully respecting Member States' choice of energy mix and sovereignty over primary energy sources and underpinned by a spirit of solidarity amongst Member States: increasing security of supply; ensuring the competitiveness of European economies and the availability of affordable energy; and promoting environmental sustainability and combating climate change. In September 2007 there was an urgent call for the establishment of a common foreign energy policy and in 2008 an action plan [7] – highlighting that security and solidarity are essential factors for energy efficiency – identified six priority areas: connecting the remaining isolated energy markets in Europe; developing a southern gas corridor for the supply of gas from the Caspian region and Middle Eastern sources; making use of liquefied natural gas to ensure the liquidity and diversity of the European Union markets; linking Europe with the Southern Mediterranean area through electricity and gas interconnections; developing gas and electricity interconnections crossing Central and South-East Europe along a north-south axis; and developing interconnections between the electric networks of the North-West of Europe so as to optimize wind energy in the North Sea.

Today, the legal basis for common energy policy is in the Lisbon Treaty in Art. 194 TFEU with the following objectives:

- To ensure the functioning of the energy market
- To ensure security of energy supply in the Union
- To promote energy efficiency and energy saving and the development of new and renewable forms of energy
- To promote the interconnection of energy networks.

A coherent energy policy framework is necessary as energy is closely linked also to other policy areas such as economic policy, *trans*-European networks, environment, transport, and industry and enterprise. The Lisbon Treaty in its economic policy under Art. 122 TFEU mentions that, based on the proposal from the Commission, the Council may decide upon appropriate measures on the economic situation if severe difficulties arise in the supply of certain products, notably in the area of energy. In accordance with Art.170 TFEU, the European Union should contribute to the establishment and development of *trans*-European networks also in the area of energy infrastructure. What regards environmental policy, Art.192 TFEU refers to a special legislative procedure affecting the Member States choice regarding different energy sources and the general structure of the energy supply.

Energy policy revolves around two major axis. The first is the internal energy market [6,8] which aims both at giving European consumers a choice between different companies supplying gas and electricity at reasonable prices, and of making the market accessible for all suppliers, especially the smallest and those investing in renewable forms of energy. It provides the common rules for the internal market for solid fuel, oil, electricity [9,10] and gas [11–13]. The internal market also depends on the development of *trans*-European networks that allow interconnection and interoperability for transporting electricity and gas. The second axis of the energy policy is the security of the energy supply which aims at ensuring that Europe's energy needs are satisfied by internal and external exportation of resources under affordable competitive prices and providing an accessible, stable and diversified energy mix. It covers the supply of coal, nuclear fuels, oil, gas, and new technologies and new energy sources. In particular new technologies and new energy sources provide an alternative option for energy security. Additionally, new and renewable energies such as wind, solar power, hydroelectric, geothermal, biomass can contribute to Europe's economic growth providing job creation.

Additionally, the European Union's research and innovation policy promotes the development of such technologies with a focus on: energy savings and energy efficiency; efficiency of combined production of electricity, heating and cooling services, through the use of new technologies, such as e. g bioenergy and hydrogen. Energy objectives are also coupled with environmental objectives requiring energy efficiency and low emissions [14].

Europe has made significant steps toward its energy policy but there is still a need to focus more on the external action to guarantee the security of energy supply. On 4th February 2011, at the first European Council explicitly devoted to energy it was concluded that "*there is a need for better coordination of EU and Member States' activities with a view to ensuring consistency and coherence in the EU's external relations with key producer, transit, and consumer countries and the High Representative is invited to take full account of the energy security dimension in her work. Energy security should also be fully reflected in the EU's neighbourhood policy*" [15].

The 2010 Commission Communication entitled Energy 2020 – A Strategy for competitive, sustainable and secure energy, identified five strategic priorities:

Achieving an energy efficient Europe; building a truly pan-European integrated energy market; empowering consumers and achieving the highest level of safety and security; extending Europe's leadership in energy technology and innovation; and strengthening the external dimension of the EU energy market [16].

The 2011 Commission Energy Roadmap identified four key aspects for achieving a more sustainable, competitive and secure energy system in 2050: energy efficiency, renewable energy, nuclear energy and carbon capture and storage [17]. Most importantly, the Roadmap concludes that decarbonizing Europe's energy system is both technically and economically feasible in the long-run. It considers the increasing share of renewable energy and a more energy efficient use across the entire region as crucial irrespective of the particular energy mix chosen. The existing aging infrastructure in the EU needs to be renewed; a common European approach is expected to result in lower costs and more secure energy supplies compared to individual national schemes as with a common energy market, energy can be produced where it is cheapest and delivered to where it is needed.

The *Investment Plan for Europe* 2014 (also referred to as the Juncker Plan) sets out the plan to support the Roadmap. The Commission's energy security package for global energy transition and energy supply interruptions touches on several topics: while continuing to emphasize the European Union's resilience to gas supply disruptions, it focusses on moderating the demand for energy and further increasing energy production from renewable sources. This serves to mature a functioning and fully integrated internal energy market. Diversification of energy sources, suppliers and routes is thus at the heart of the European Union's roadmap on energy.

Proposals made for the European energy market in the plans include amongst others to seek new perspectives of the new global and universal agreement on climate change, clean energy and energy transition, a focus on heating and cooling strategies in buildings and industry as well as clear call for smart and sustainable cities from an energy point of view. These proposals should lead to half of the generated electricity in Europe to be provided by renewable energy sources by 2030, and enable Europe to go carbon free in a timeframe of about 35 years (reducing greenhouse gasses by 80–95% by 2050).

The Junker plan has to sustain a competitive low-carbon economy, which has led the European Fund for Strategic Investment to prioritize projects enabling to reach this goal, including riskier projects and those promoting renewable energies.

The 2014 *Commission Communication on Climate and Energy Policy from 2020 until 2030* [18], recognizes the impact of humans on global climate change and of the need for substantial and sustained reductions of greenhouse gas emissions to limit said impact. For 2030 the following targets were identified:

- lowering greenhouse gas emissions by 40%, compared to emission levels of 1990;
- share of renewable energy consumption of at least a 27%;
- at least 27% energy savings compared with the business-*as*-usual scenario.

The European Commission further proposed to reform EU emissions trading scheme (ETS) and to find new indicators for the competitiveness and security of the energy system to meet the targets. A new governance system based on national plans for competitive, secure, and sustainable energy following a common EU approach is also envisioned. They will ensure stronger investor certainty, greater transparency, enhanced policy coherence and improved coordination across the EU.

In the *2050 Energy Strategy*, the EU has set itself a long-term goal of reducing greenhouse gas emissions by 80–95% when compared to 1990 levels by 2050. The Energy Roadmap 2050 explores the transition of the energy system in ways that would be compatible with this greenhouse gas reductions target while also increasing competitiveness and security of supply [17,19].

Table 1 summarizes main energy policy interests as describes in the strategy documents above, and demonstrates how space assets con contribute to those policy objectives. Concrete examples highlight the potential of navigation, Earth observation and Telecommunication technologies for achieving energy policy objectives.

3. ESA initiatives and programmes supporting energy objectives

Through its initiatives and programs, the European Space Agency (ESA) has been contributing to the European energy strategic policy objectives described in the previous section. ESA and the Directorate General for Energy and Transport of the European Commission organized on 15 January 2010 a workshop with experts on "*energy and space*". This workshop brought 60 experts from industry and academia from both national and international administrations together to discuss opportunities, explore synergies and assess the potential benefits of intensifying cooperation between the energy and space sector.

There was broad consensus that space technologies and applications can significantly contribute to improve security of supply and support the transition to a low carbon economy. While at the time of the workshop there already were concrete examples illustrating the potential benefits

Table 1
Space as an asset for energy policy.

	Energy Policy		
Policy Areas and Main Objectives	Ensure the functioning of the energy market; Ensure the security of energy supply and energy saving; Promote the energy-efficiency and –saving; Development of new and renewable forms of energy; Ensure the competitiveness of European economies; Ensure the availability of affordable energy; Promote environmental sustainability; Combat climate change.		
	Navigation	**Earth Observation**	**Telecommunication**
Contribution by Space Asset	Improved control of energy infrastructures;	Surveying;	Provides use of data free of charge
	Improved power flow;	Providing electrical grid	New business opportunities in the services market;
	Improved time-synchronization of power-related instruments;	Power supply	Development of the labor market to meet the demand for new services and technologies.
	Increased safety and efficiency in oil exploration;	Pipeline monitoring	Improvement of Europe's competitiveness
	Improved control of drilling facilities;	Improve knowledge concerning mineral deposits	Protection of information in the electronic exchange of documents and computer files related information society, security, data integrity, authenticity and confidentiality
	Timely decision-making thanks to faster positioning information, even in remote areas;	Bolster the efficient use of natural resources	
Examples	Network synchronization for power generation and distribution	Production of renewable energy services: providing e.g. UV and solar energy services based on the ozone and aerosol global data assimilation results, estimation of wind or hydropower production	Fast streaming of large volumes of data to remote areas
	Facilitating maintenance and planning in both rural and remote areas	Monitoring gas emissions and environmental parameters of pipelines, wind turbines or power pylons in remote areas	High temporal resolution on ground data, allowing the integration of existing infrastructures for integrated applications
	Exact and accurate control of all assets in complex systems, fast response times	Surveying and evaluating remote areas for development of natural resources	
		Design, construction and operation of large networks for the development of energy applications	

of this cooperation (e.g.: space surveillance and assessment of energy infrastructures and renewable resources; technology transfer in sectors concerning renewable energies such as photovoltaic or hydrogen; or research on innovative motor fuels), it was clear that energy and space stakeholders are not only different but also have little tradition of working together [20]. While further potential areas for cooperation were identified, the discussion on the importance of space was valuable and sought to be translated into concrete actions. A comprehensive overview can be found in [21].

An overview is provided below of existing programs and initiatives with potential applications or an explicit focus on technologies beneficial to the energy sector.

Space technology has a number of applications in the Energy sector, particularly in renewable energy sources as well as in traditional oil-carbon and nuclear sectors. Telecommunications, Earth Observation (EO) and Navigation (NAV) can enormously assist and facilitate the design, planning and establishment of large, regional projects – also beyond the Europe's borders. Integration of terrestrial and space technologies can provide a wide spectrum of applications an interface with existing applications and further a potential to support energy policies. These integrated applications can combine terrestrial and satellite data with complex modelling. In particular after the adoption of the *Space and Energy Initiative* – as a cross-cutting technology theme – at the ESA Ministerial Council of 2012, the agency has made efforts to strengthen technological synergies with the terrestrial energy sector [22].

3.1. Telecommunications and integrated applications

ESA ARTES is a program aiming to transform state of the art research and development activities into operational, profitable and self-sustaining products and services within Europe. This successful program is the result of the consolidation of public-private partnerships between all key elements of the space industry, service providers, organizations and user communities within participating Member States. While the ARTES programs are dedicated to funding and promoting the general development of all space-based applications, services and solutions to cater for the needs of European citizens and the society at large, the subject of energy has recently become a one key focus of the ARTES program. In the following selected ARTES projects are highlighted, showing the potential for new cooperation supporting energy policies.

In particular, Table 2 provides an overview of select activities within the frame of the ARTES program serving energy policy interests. The project "*Concentrating Solar Power Forecast System For Participation In The Spanish Electricity Market Using EO And telecom Technologies*" (CSP-FOSYS [23]) is such a project: by forecasting the weather and thus the output of a parabolic solar power plant in Spain, the operators can avoid the risk of fines for inaccurate forecast, while the engineering questions ranging from implementing to running such a power plant can be addressed in a structured way previously not accessible to the conventional energy market. This project also brings together entities that have not previously cooperated, like in this case the German Aerospace Centre (DLR) and a SME. Without the ARTES program, such a project would not have been attempted. It also serves as an example for the high risk involved in such projects, as the primary contractor filed for bankruptcy after the initial

Table 2
ARTES initiatives serving energy policy purposes (see also [25]).

Project	Main focus and application to Energy Sector
GRIDWATCH	Information on high voltage power infrastructures for their maintenance and electrical energy distribution.
SEWISS	Support onshore wind developers with the data for screening and selecting suitable development sites using an online portal. Relevant, high resolution EO, and non EO data layers can be accessed and automatically pre-processed (land cover, rooftop recognition, green field, turbine selection and positioning analysis, …)
SUMO	Assist in planning and monitoring of marine operations for offshore wind farms by integration of diverse information regarding of weather/oceanic conditions, locations of vessels and personnel involved. Enabling management and coordination of the construction, operations and maintenance activities to increase efficiency and safety.
HV-SATPROTEC	Feasibility study on new electricity infrastructure management services using space assets
SPACEGRID	Promotion of integration of state-of-the-art satellite telecommunication and Earth observation technologies with power grid management systems. Thousand km of lines throughout the national territory
SHARPERSAT	Improvement of maintenance and recovery of high voltage electricity transportation infrastructure using SatEO, GNSS and data obtained by Unmanned Aerial Vehicles.
SURMON	Targeting airborne geophysical surveys and oil pipeline monitoring services based on the use of Remotely Piloted Aircraft System (RPAS) operated using satellite communication and GNSS beyond line-of-sight of pilots
UASATCOM	Similar scope as SURMON, focused on an Unmanned Aircraft Systems (UAS) for beyond line of site operation
PIMS	Pipeline Integrity Management System for monitoring all activities to ensure safe and continuous operation of pipe line.
INTOGENER	INTegration of EO data and GNSS-R signals for ENERgy applications for demonstration of operational capabilities of a water flow monitoring and prediction system aimed at hydro power production and water management organizations.
CSP-FOSYS DP and CSP-FOSYS	Forecast of solar thermal power production of large plants (up to 250 MW) of both day-ahead and intra-day. This information is required to successfully integrate large solar power plants into existing infrastructure using numerical weather prediction and satellite-based data.
PROFUMO	Operational weather routing services for the maritime community, based on cooperative collection of meteo-marine data from commercial vessels. Acquired data is used to provide enhanced meteo-marine forecast and nowcast capabilities on a local scale.
WIAP	Identification and realization of benefits for the wind power service industry by integrating new and/or improved space capabilities. By focusses on the users/stakeholders of the wind industry, the aim is to identify potential gaps in the infrastructure.
ISSWIND	Definition of Supporting Services for the Wind Power Industry with focus on possible use of space technology, assets or products and its added value, gaps and possible improvements.
CCS SpaceMon	Integration of EO, GNSS and Telecommunication to support the monitoring of future CO_2 storage sites as part of Carbon Capture and Storage (CCS) technology.
ThermCERT	City wide, impartial situational awareness at high resolution on thermal performance of buildings to identify ineffective use of energy. An effective and sustainable solution from space for better temporal resolution and spatial coverage compared to conventional methods.
SnowSense and SnowSense DP	Provision of snow, run-off and hydropower information for remote areas as a combination of in-situ snow monitoring, EO and model techniques as innovative solution for snow cover assessment. Allowing to assess both potential of stored water for energy production as well as estimation of flood risks
Com4Offshore	Feasibility study of the technical and commercial viability of an integrated communication system, enabling a multimodal usage of communication infrastructure and services for offshore wind park construction. Such system would include a simplified, reliable and cost effective exchange of voice, video data and positioning information between contractual partners of offshore construction activities
Transparentforests and Transparentforests FS	Web based GIS mapping and data management service to increase the credibility and transparency of the Forest Stewardship Council certification process and monitor and improve operational efficiency across the certification service delivery chain. Reduction of environmental aspects of using forest products such as paper, wood and composite materials in applications such as e.g. energy generation.
Cerberus: Forest Falcon	Flexible crowdsourcing system integrating EO data for monitoring forest degradation

project phase. However, thanks to ARTES framework funding the project was continued as CSP-FOSYS – DP with a new primary contractor.

INTOGENER (*INTegration of EO data and GNSS-R signals for ENERgy applications* [24]) is aimed at demonstrating the operational capabilities of an integrated system for water flow monitoring and prediction to support hydropower production. It found successful integration as a pilot project in Chile. An accurate forecast of available water flow, snow cover, wind patterns or solar irradiation is crucial for renewable power production technologies. In particular because the conventional power grids are not designed to deal with large fluctuations of input power and may not be able to meet the energy demand for large populations over the year. Space technologies can thus also add value to those conventional power distribution networks, which is particularly evident from the following project.

GRIDWATCH supports both the maintenance of a conventional power infrastructure as well as network operations and energy dispatching:

- GNSS for the continuous assessment of the pylons and their displacements in conditions where terrain is subject to landslides and slow movements;
- EO weather data as part of an integrated system to support the energy distribution by assessing current environmental conditions
- Synthetic Aperture Radar satellite data to measure displacements of objects on the ground.

While using satellite communications is not crucial for the service deployment, it is an affordable alternative for remote areas where terrestrial telecommunications are scarcely available. Conventional grids often give rise to such cases, considering that high voltage networks are generally designed to avoid populated areas.

3.2. Earth observation

A number of Earth observation related project within the ESA Earth Observation programs have been developed over the years with direct or indirect support to various energy policy objectives.

The Earth Observation Envelope Program (EOEP), is the backbone of all ESA EO activities and represents a stable planning environment for new types of environmental sensing technologies It consists of two main components:

- The *Earth Explorer* component (see below) which involves the development and launch of new types of EO spacecraft.
- The development and exploitation component, encompassing preparatory activities for future missions as well as end-to-end preparation of mission.

The Living Earth Program (LEP) is part of ESA's EO program, encompassing a number of on-going and upcoming EO missions. They are referred to as the *Earth Explorer* missions, as their primary focus is on the atmosphere, biosphere, hydrosphere, cryosphere and Earth's interior, crucial to integrated energy applications and –technologies, combining telecom, EO and navigation assets.

In the framework of its Space & Energy initiative, ESA commissioned two studies in 2013 to be carried out to increase the synergy between the Energy Sector (ES) and the Space sector and to assess how the space sector, and in particular Earth Observation (EO) programs could contribute [26].

The first study proposed the following new missions: GEM (***G**reen House Gas **E**missions Future **M**ission Concept for Sustainable Energy Use*) and WiRM (*Future Mission Concept for Offshore Operations And Wind Power*). GEM develops Sentinel-5 and Sentinel-4 potentialities for GHG source monitoring via products with improved vertical resolution and improved sensitivity near the surface, by combining instruments in different spectral domains. WiRM evaluates the benefit of METOP-B (2012)/METOP-C (2017)/ASCAT (surface wind) combined with MTGI1 (2018)/IRS (Atmospheric Motion Vectors: 3D winds) in NWP models through data assimilation [27].

The second study proposed HADES, a Carbon Capture and Storage (CCS) and HiTIR aimed at the detection of thermal leakages. The HADES concept is based on localisation of sub-surface saline aquifers suitable for CCS via Ground Penetrating Radar (GPR) from orbit. HiTIR aims at increasing the efficiency of thermal insulation via **H**igh resolution **T**hermal **I**nfra-**R**ed imagery detection leakages [27].

Copernicus, previously known as Global Monitoring for Environment and Security program (GMES) is the most ambitious EO program to date headed by both the European Commission and ESA. It aims to provide accurate, timely and easily accessible information to improve the management of the environment, understand and mitigate the effects of climate change and ensure civil security.

Once fully implemented, EO data from over 30 satellites will be available [28]. On one side, the Sentinels satellites are specifically designed for the operational needs of the Copernicus program, carrying a wide range of technologies for land, ocean and atmospheric monitoring. Data from a number of instruments and satellites operated by the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) or from contributing missions operated by national, European or international organizations complete the wealth of data for Copernicus services.

3.3. Navigation

Navigation applications contribute foremost to the real-time delivery of tracking energy use and conservation. ESA has supported a range of companies as they develop business ideas for smart energy use, and the Agency continues to support the *Galileo Masters competition* for innovative use of satellite navigation.

An example for the use of Navigation data from Space is *Carbon Diem*, a smartphone application developed by the ESA-supported company Carbon Hero. The app is the first automated carbon calculator. It monitors the person's movements but still guarantees the carrier's privacy. The software uses satellite navigation data to calculate the environmental impact of travel and can determine the type of transportation being used, and how much energy that consumes with very little input from the user. The carbon footprint of the user can then be calculated [29].

Satellite navigation data is also used to optimize fuel efficiency in transport. *GreenDrive* combines information a vehicles location, road conditions and type of car being used, to calculate and advise the driver on the most economical driving style to use. Using audio prompts to advise the proper velocity, the inventors claim that these smooth and safe driving techniques can lead to energy savings of 15–25% [29].

3.4. ESA's technology transfer program (TTP)

The TTP works to share the benefits of ESA research and development, making space sector technologies available to the rest of European industry. On one side, it aims to identify industrial needs and maps them to suitable space technologies as a way of both enabling new applications and as well as business opportunities. On the other side new businesses are supported based on the transfer and use of space technologies, including products and services for the energy sector.

The technology transfer process is carried out in several different ways:

- By the *Technology Transfer Network* involving technology brokers;
- Through national technology transfer initiatives;
- Through opportunities announced on the Technology Transfer Forum online market place;
- ESA Business Incubation Centres.

As an example for a successful practical realization of the work of TTP is its role in helping to achieve energy policy objectives is e.g. the

ActInSpace contest, and event co-organized by the French Space Agency CNES, ESA and the ESA Business Incubator Centre Sud France. The 2016 winner was *Happy-fleet*, an application for drivers to increase fuel efficiency. The technology was based on an adaptation of CNES patented technology designed to optimize satellite fuel efficiency [30].

As another example, the experience with complex EO and telecom satellites has led to the development of zero-emission air-conditioning system, bringing mankind tangible steps closer to Zero-carbon buildings [31].

3.5. ESA basic technology research program (TRP)

ESA's TRP enables researchers to explore new ideas from the very earliest stages. It aims to support the investigation of fundamental, new ideas (or blue-sky thinking) in-line with the Agency's objectives and is the only technology program that supports all Agency's directorates across the entire spectrum of technical disciplines. The TRP deals with so-called *Generic Technologies*, either of potential use to multiple missions or else advanced basic technologies of common interest to all applications, such as component design, spacecraft propulsion or power generation.

Within TRP, the *Energy and Space* initiative aims to strengthen technological synergies with the terrestrial energy sector. Not only decades of experience in non-carbon power systems for space applications such as e.g. solar cells, but also the further development and preparation of new energy technologies for e.g. energy storage and hydrogen power are promoted.

Aside from that, thermal control is another space technology area of interest for TRP that could potentially contribute to more effective methods of cutting heat loss, reducing overall energy needs or to remove waste heat (cooling). Advanced robotics and remote control could help with both energy prospecting and production for e.g. isolated solar plants might be entirely teleoperated.

4. Concluding remarks

The European Union's main lines in energy policy enclosed in its *Energy Strategy 2020–2030–2050* can be described as follows:

- Ensure the functioning of the energy market;
- Ensure the security of energy supply and energy saving;
- Promote both energy efficiency and energy saving;
- Development of new and renewable forms of energy;
- Ensure the competitiveness of European economies;
- Ensure the availability of affordable energy;
- Promote environmental sustainability;
- Combat climate change.

Space assets can contribute to achieving those energy policy objectives via navigation, Earth observation and telecommunication assets and applications, with specific purposes identified in the paper.

Multiple ESA initiatives and programs already serve the outlined energy policy objectives. ESA has established multiple initiatives and programs that finance the development of space assets, technology and applications that deliver services in support of the EU energy policy and sector. These programs are found across ESA's programmatic activities in the various directorates, including mainly Earth observation, telecommunications, integrated applications and Navigation, but also in science, basic activities and technology development. This reaffirms the broad range of space assets and applications useful for energy policy purposes.

The listed initiatives and programs show the extent of the usefulness and effectiveness of space assets and applications in support of energy policy objectives. The efforts made for the role of space in support of energy policy should be continued and strengthened to deal with short and long term technological challenges to achieving the objectives set forward in the *Energy Strategy 2020–2030–2050*.

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