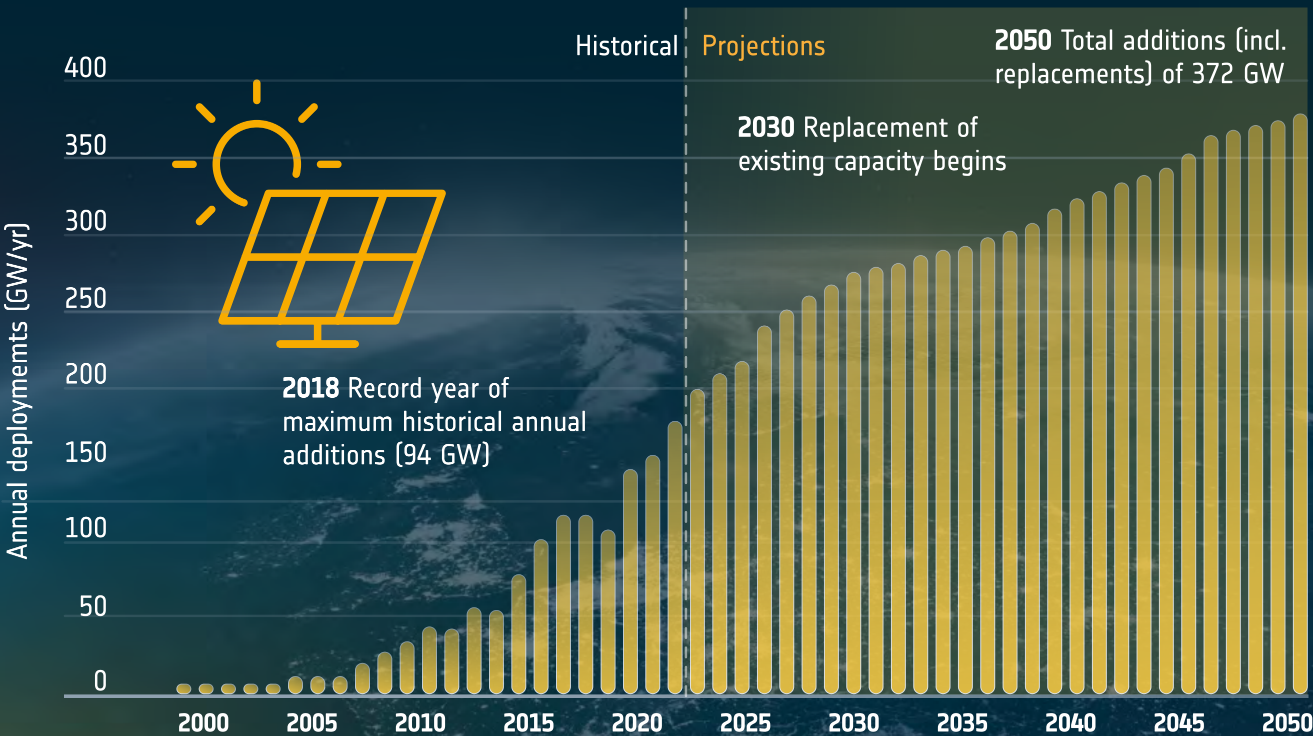
SPACE FOR SOLAR ENERGY: USE CASES AND MARKET OPPORTUNITIES

The rise of the solar energy sector

Renewables are on the rise worldwide, a phenomenon in which solar energy is playing a particularly important part. In 2022, global installations amounted to 268 GW of new solar capacity, with this figure expected to rise to 315 GW in 2023[1]. In the next decade, installations of solar photovoltaics (PV) are expected to increase sixfold reaching a global capacity of 2,840 GW by 2030. The International Renewable Energy Agency (IRENA) expects solar photovoltaics and wind power to lead the electricity market transformation by 2050, with solar power becoming the second largest source and covering 25% of global electricity needs. Worldwide PV capacity is expected to consist of 40% distributed (rooftop) and 60% utility-scale power. In particular, distributed solar PV installations are expected to grow rapidly as a result of consumer engagement and supportive policies[2].

With electricity demand projected to continue to grow, and with access to energy among the Sustainability Development Goals (SDG 7), solar offers unique added value in providing access to clean energy. Off-grid solar solutions, for example, grew by 18% in 2022 in developing Asia and sub-Saharan Africa[3]. In total, since 2010, more than 180 million off-grid systems have been sold, including 150 million pico solar products and 30 million solar home systems.



Annual global solar PV additions are expected to reach to 270 GW in 2030 and 372 GW in 2050 under the REmap scenario, compared with 94 GW in 2018 (source: Own illustration based on IRENA and IEA data, 2023)

1. GLOBAL SOLAR CAPACITY ADDITIONS HIT 268 GW IN 2022...
2. FUTURE OF SOLAR PHOTOVOLTAIC – A GLOBAL ENERGY...
3. CUMULATIVE GROWTH OF OFF-GRID SOLAR PV APPLICATIONS...

European solar energy landscape and stakeholders

In Europe, almost 40% of total electricity was generated by renewables in 2022. Solar was the most competitive source, with a total capacity of 209 GW (50% year-on-year growth rate), and could reach up to 1 TW by 2030 (672 GW in a business-as-usual scenario)[4]. To make this possible, and complementing national actions, the European Commission presented further steps to speed up solar deployment in the REPowerEU package, which provides new guidance on enabling a Solar Rooftops Initiative, a Solar Photovoltaic Industry Alliance and a Solar Skills Partnership.

Today, the top five EU solar power markets are responsible for two thirds of the installed capacity in the region. Some of the largest European solar asset owners are Enerparc, Encavis, Octopus (through partnership with Lightsource BP), the Foresight Group, Sonnedix and Encavis.

In many countries, solar PV is already cheaper than retail electricity, but further application will depend, particularly for utility-scale projects, on national regulations on aspects such as auctions, tenders, feed-in tariffs, feed-in premiums, sun taxes, net-metering options (e.g. the Netherlands, Poland) and building, among others. At the consumer level, demand for home installations in the form of PV plus storage is increasing for energy price security and autonomy reasons. The number of new “prosumers”[5] in Germany, for example, was already estimated at 100,000 in 2019. Urban areas hold vast potential for solar energy: 90% of European rooftops are currently unused, offering a total estimated installed capacity of around 80 GW. The potential is estimated to be 680 TWh, or 25% of current electricity consumption, according to the European Commission's Joint Research Centre (JRC)[6]. Decentralised solar installations (15.1 GW) are forecasted to exceed utility-scale installations (14.2 GW) by 2028. Building roofs and facades (building-integrated photovoltaics) in urban and non-urban areas will become more attractive in the future, and several cities have already initiated pilot projects. New applications for PV modules include building-integrated PV, agriphotovoltaics, vehicle-integrated PV, floating PV and road-integrated PV. New hybrid solutions are also being installed. It is estimated that Europe could generate 25 GW of capacity using inland waters and 45 GW from the sea[7]. Considerations of energy autonomy and energy diversification, will show in how far large-scale projects like Desertec will experience a revival.

Europe has traditionally been a leader in R&D on PV. Fraunhofer Gesellschaft, for example, developed the world's most efficient solar cell[8]. Yet, when it comes to solar PV production, the EU has fallen behind, with no European company currently among the top ten producers. Hopes are pinned on new materials, such as bi-facial PV modules, and new PV technologies, such as perovskite solar cells, that can further increase efficiency but also strengthen European competitiveness.

EUROPEAN COUNTRY	GERMANY	SPAIN	POLAND	NETHERLANDS	FRANCE
POSITION (2022)	1 ST	2 ND	3 RD	4 TH	5 TH
NEW INSTALLED CAPACITY	7.9 GW	7.5 GW	4.9 GW	4.0 GW	2.7 GW

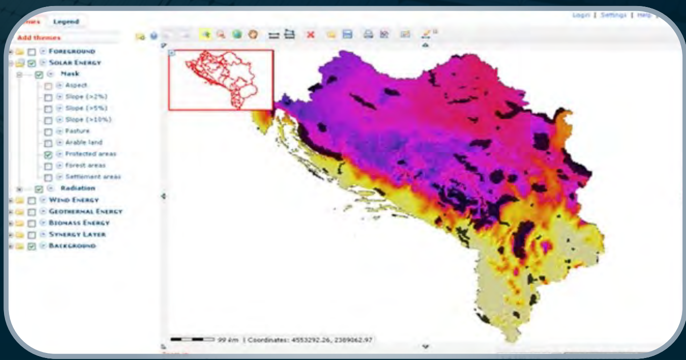
4. NEW REPORT REVEALS EU SOLAR POWER SOARS BY...
5. PRODUCER-CONSUMERS
6. OCEAN ENERGY: TECHNOLOGY MARKET REPORT...
7. TREND PAPER FOR INTERSOLAR EUROPE: FLOATING PHOTOVOLTAICS...
8. FRAUNHOFER ISE DEVELOPS THE WORLD'S...

Solar energy sector trends and needs

The energy transformation is characterised by increasing decentralisation, digitalisation and electrification, which is driving the need for data and Energy-as-a-Service (EaaS) and Energy-Data-as-a-Service (EDaaS) models. Weather, environmental data and land information are becoming key factors, even in real time. The following space-related use cases have been identified as being of the greatest commercial relevance.

Location scouting and due diligence

Finding a location that maximises output potential is a key factor in solar energy production at both commercial and private levels, at utility scale, and as a prosumer. Location assessment will become more diversified and will include deserts, rooftops or water bodies. Rooftops need to be assessed for inclination angles or obstacle obstruction, among other factors. Data plays a crucial role in deciding where to place solar systems, since mapping of remote locations can provide historical and forecasted data on each location's potential. Factors considered include solar irradiance, air quality and cloud coverage, as a lack of sunlight can limit efficiency, affecting the economics of solar projects. Banks and investors need to understand the bankability of planned new projects. With new financing options such as solar leasing and power purchase agreements, this need is further increasing.



Balkan Renewable Energy Potential mapped by GeoVille[9]

System planning and forecasting

With a growing number of small power producers, the need for mapping and planning of new energy sources is important both in terms of productivity and the socioeconomic environment. Governments and energy operators need to locate optimal areas for new power installation, taking account of mid- and long-term energy needs and supply. Real-time weather data, and especially solar irradiance and clear-sky information, are becoming more important, with changing feed-in tariffs and stronger market pressure. Solar power requires planning and forecasting to ensure that its energy is used more efficiently. Flexibility will also be provided by storage facilities, active demand management and increased grid interconnectivity. With a greater number of prosumers in the market, multidirectional flows of energy and information are required.

Installation of a solar power plant, container battery energy storage systems

9. GEOVILLE: GEOVILLE INFORMATION SYSTEMS AND DATA...

Maintenance and connectivity

With the diversification of solar PV applications, communication requirements are increasing for remote areas, and for water bodies in the case of floating PV. Utility-scale solar farms face high cost pressures, and regular site monitoring and analysis is important to identify any anomalies in production.

Predictive, automated maintenance is required to detect inefficiencies before equipment needs to be replaced. Drones may need to be directed to clean solar panels to ensure they retain their full functionality (via remote thermographic imaging of facilities). Maintaining the installation is crucial to ensure the longevity and optimal performance of the sites. Workers and drones often work together to clean sites, inspect, test and perform repairs.

Photovoltaic installation maintenance

Energy efficiency, electrification, and prosumers

Prosumers and the increasing electrification, refers to that active end-use sector who not only buys energy, but produces, stores, and eventually sells the created energy into the network, greatly increasing the load on distribution networks. Smart meters will support managing devices, balance consumption, and increase energy efficiency of electrified sectors.

Distributed solar PV

Environmental impact and protection from natural hazards

New PV installations, such as floating or agro-PV, have to show their harmfulness to their local environment during pilot phases as well as mid- and long-term use (e.g. existing habitats, biodiversity). Moreover, installations should be protected against natural hazards. The vulnerability of the site must be assessed by identifying risk zones and by monitoring external threats.

Solar Farm

Added value of the space sector

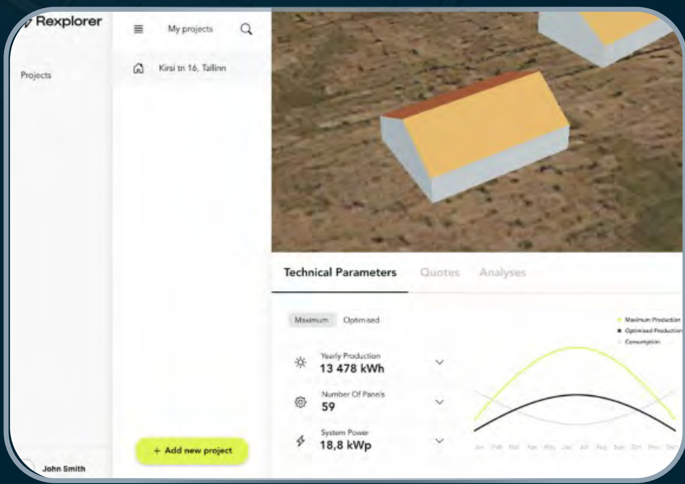
Sixty years ago, solar cells brought about a coming together of the space and energy sectors for the first time. Today, the predicted increase in new installations, the need for greater efficiency, and the dependency on environmental information is opening up new commercial and scalable opportunities for space-based applications and services.

Geospatial data is of critical importance in identifying suitable locations by **mapping solar geometry** (solar noon, daylight hours, hourly solar angles from the horizon), radiation, insolation, clear-sky days and illuminance. Publicly available data, from Sentinel-4 for example, serves as the basis for many downstream services for the solar sector, such as location scouting, planning, monitoring, efficiency improvements and the integration of solar energy systems. This information forms the basis for Copernicus Atmosphere Monitoring Services[10]. This space-based data also feeds into various tools such as the **Photovoltaic Geographical Information System (PVGIS)** offered by the JRC and the Global Solar Atlas, administered by the World Bank and developed by Solargis. It offers, among other things, visualisation of global solar resources, power potential and yield calculations and feeds into other tools such as the Global Solar Atlas for Renewable Energy by IRENA and RETScreen[11].

Various start-ups have been emerging to provide further services to the growing number of new customers. Rexplorer[12], a company incubated by the ESA BIC[13] Estonia, generates digital twins of rooftops for the installation of solar PV. The company combines 3D modelling, satellite data and on-demand API services for solar energy developers and other partners such as smart city energy planners.

Sentinel-4 measuring, among others, Earth and Solar irradiance

The artificial intelligence is trained to use any type of building satellite imagery and recognise obstacle objects to then determine, with a high level of accuracy, the scalability of the energy potential in that specific location. Solutions are also being developed by Glint Solar[14], which uses satellite altimetry and multispectral imagery along with machine learning to identify and evaluate the best sites for floating solar power, taking into account engineering criteria, local climate conditions, logistics considerations and more (ESA BIC Norway).



Rexplorer indicating rooftop potential based on the inputted household address

Reveal AI[15], for its part, exploits satellite data from ESA BIC Hessen (Germany), while Solartechno[16] offers a modular, autonomous, plug-and-play photovoltaic electricity product based on space technology. Another example of technology transfer is Polar Developments[17], a company that uses ESA-patented modular deployment technology and offers near-instantaneous high-capacity photovoltaic generators.

10. COPERNICUS ATMOSPHERE MONITORING SERVICES...
11. GLOBAL SOLAR ATLAS...
12. REXPLORER...
13. BUSINESS INCUBATION CENTRE...
14. GLINT SOLAR..
15. REVEAL AI...
16. SOLARTECHNO...
17. POLAR DEVELOPMENTS...

START-UPS

Rexplorer | Glint Solar | REVEAL AI | SOLARTECHNO | POLAR DEVELOPMENTS

Examples of companies supported by ESA

With the increasing numbers of distributed solar panels being installed, there is a growing **need to map commercial and private solar panels and capacity** to improve grid planning and evaluate policy measures or identify gaps. The use of Sentinel-2 data, complemented by private constellations such as SPOT from Airbus[18], has resulted in successful synergies when using innovative data science models.

Solar panel management software and tools are on the rise in a context of increasing competition. While RETScreen is one of the best known, other new solutions are also emerging to improve planning, forecasting, maintenance and inspections. GNSS and IoT communication via satellite can support drones and other remotely piloted aircraft in automatic photovoltaic plant inspection and data exploitation[19].

Astradyne's SolarCube[20]

The **solar energy transition is also taking place in space,** as spacecraft rely on solar energy. The Sun has greater energy potential in space, where it is the main source of energy[21]. Space-based solar power (SBSP) projects are among the most inspirational initiatives as they aim to harvest unlimited green energy from space and transmit it wirelessly back to Earth. Solar energy potential is over ten times greater in orbit than on Earth due to higher solar illumination, unfiltered by atmospheres, and non-dependence on weather conditions. SBSP can thus balance out the intermittent nature of other terrestrial renewable sources. Such systems have the potential to provide 100s of GWs of constant power to Earth at a build cost comparable to large terrestrial engineering projects.

It is for this reason that ESA has established the SOLARIS R&D initiative to mature SBSP concepts and technology by 2025. A decision on whether to embark on a full European development programme will be made, aiming to deliver clean, affordable, continuous, abundant and secure energy, 24 hours a day, seven days a week, during the 2030's. "The concept has been around for decades and is expected to be feasible because the building blocks are already there", says Sanjay Vijendran, Head of the SOLARIS initiative. He believes that Europe already has all the required technological expertise, but more advancement is needed in technologies such as radiofrequency power beaming, large modular antennas, large-scale robotic in-orbit construction and manufacturing, low-cost solar cells, and more to confirm both technical but also economic feasibility.

In conclusion, renewables are on the rise and solar leads the green energy mix, giving place to high investments in R&D, new technologies and environmental crisis solutions. This sector is expected to continue growing resulting in interesting commercial opportunities for space related companies.

18. ICT INSTITUTE | USING AI TO COUNT ALL THE SOLAR...
19. AUTOMATIC PHOTOVOLTAIC PLANT INSPECTION...
20. HOMEPAGE - ASTRADYNE...
21. New innovations are also being developed for spacecraft: Astradyne's SolarCube is an origami-inspired solar panel characterised by a high stowed-to-deployed surface ratio and lightness.