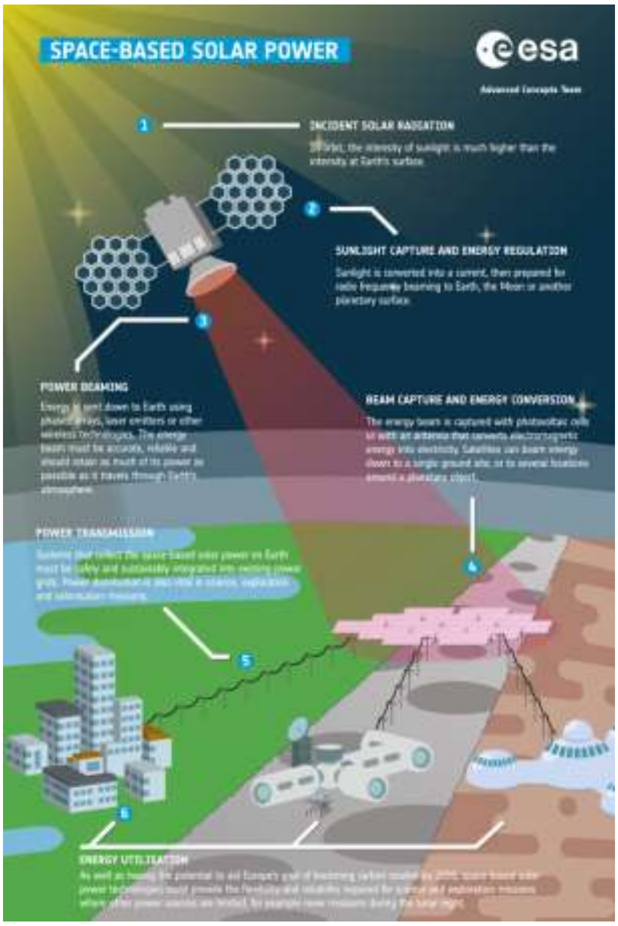
ESA/NASA Re-ignite Space-based Solar Power Research

Compiled by J. Kehr, Editor, July 2022

ESA Research Status: January 2022: [1]

"We urgently need solutions to tackle climate change on Earth".
Meanwhile, the space sector is working hard to make space exploration more sustainable. ESA is targeting both ambitions by enabling European academia and industry to take further steps towards Space-Based Solar Power (SBSP).



For satellites orbiting high above Earth, outside the atmosphere, sunlight is on average more than 10 times more intense than on the ground in Europe. SBSP satellites could also face the Sun all day every day to continuously capture the maximum amount of light possible. The satellites could then beam energy down to Earth, the Moon or other planets.

But SBSP technologies are still in their very early stages of development. ESA hadn't seriously investigated the topic since 2006, so ESA's Discovery program recently called for ideas that would answer the question: ***how do you convert a large amount of solar energy into a useful form and beam it down to Earth*** or another planetary surface, as efficiently as possible?
Of 85 ideas received, 13 were selected for funding. The activities have all recently launched to explore a diverse range of SBSP technologies, including how to more efficiently collect sunlight and how to safely transmit this power to Earth, as well as how to manufacture and assemble these huge solar power satellites, control them and keep them in the right location.

In 1923 Hermann Oberth already wrote in his rocket-pioneering book "The Rocket into Planetary Space" in chapter 17, "Outlook" about the usefulness of a space station:

"This station would have some practical use, but the following would be even greater: One could spread out a circular wire net …inclined to the rays of the Sun by 45°. Now by proper positioning of the individual facets, one could concentrate, as needed, all the solar energy reflected by the mirror to single points on Earth."

Design Principles

Space-based solar power essentially consists of three elements: [2]
1. Collect solar energy in space with reflectors or inflatable mirrors onto solar cells or heaters for thermal systems.
2. Wireless power transmission to Earth via microwave or laser.
3. Receiving power on Earth via a *rectenna* (rectifying antenna, is a special type of receiving antenna that is used for converting electromagnetic energy into direct current (DC) electricity, or a microwave antenna.

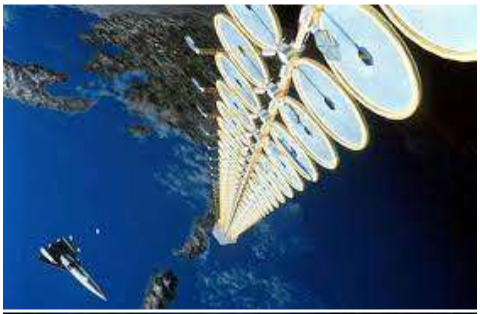
The space-based portion will not need to support itself against gravity (other than relatively weak tidal stresses). It needs no protection from terrestrial wind or weather, but will have to cope with space hazards such as micrometeorites and solar flares.
Two basic methods of conversion have been studied: photovoltaic (PV) and solar dynamic (SD). Most analyses of SBSP have focused on photovoltaic conversion using solar cells that directly convert sunlight into electricity. Solar dynamic uses mirrors to concentrate light on a boiler. The use of solar dynamic could reduce mass per watt.
Wireless power transmission was proposed early on as a means to transfer energy from collection to the Earth's surface, using either *microwave* or *laser* radiation at a variety of frequencies.

The European Space Based Solar Power (ESSP) assessment was summarized earlier in a paper by Leopold Summerer in 2002 [3], when gas and fossil fuel still was aplenty. The than derived principles were:
"Key technologies enabling solar power from space progressed substantially, though roughly following the expected general advances envisaged 10 years ago. On the other hand, the environment for the introduction of radically new types of energy systems has undergone almost revolutionary changes since the first publication of the European SPS Program Plan in 2002. The drastic change in the general public perception of the need for real changes has been stronger than anticipated, opening a new window of opportunity for a fresh look at space solar power. Based on the above-mentioned general changes, the following preliminary conclusions are proposed to guide such a fresh look at space solar power, using a special emphasis on the European situation: The energy policy of the European Union is expected to provide the basis and incentives for substantial changes in the European energy infrastructure, including a maintained strong support for the further increase of the share of renewable, and especially solar power sources. The rapid development of the terrestrial solar power PV market, accelerated recently by the massive entry of Chinese production will further increase the competitiveness of largescale terrestrial solar power plants. The anticipated substantial increase of the share of terrestrial solar power plants is expected to increase the need for the addition of reliable and large-scale energy storage solutions; above a certain total threshold for power from solar energy, energy storage requirements for largescale solar power plants might drive terrestrial plant costs.

A real market for large scale terrestrial solar power plants in North-Africa and the Middle East connected to Europe is technically realistic; ongoing and planned private and public investments in such an infrastructure are encouraging and allow the anticipation of 100s of MW to GW scale installations in a 2025+ timeframe. An orbiting prototype proof of concept of an entire space solar power system is realistic to be assumed in a 2020+ time frame. Contrary to most traditional space applications, the technical aspects of any service from space for the energy sector, including space solar power need to be secondary and driven by economic and service considerations; space for energy needs to be approached radically different than space for science, space for knowledge or space for defense applications; long-term, stable energy sector driven public private partnerships seem to be suitable implementation mechanisms; contrary to most solar power from space studies in the past 30 years, the space solar power system needs to be conceived and seen as a complement to and fully integrated into a future terrestrial energy infrastructure, not in opposition to other (terrestrial) options to increase the sustainability of the overall energy system."

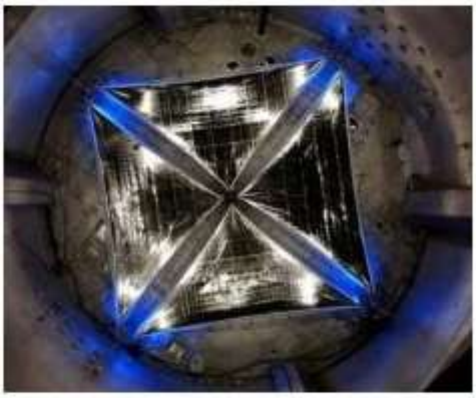
Technology

Although Oberth's proposal to mirror sunlight directly to Earth turned out to be not feasible, his basic idea to capture sunlight outside the earth's atmosphere and bring its energy to Earth has grown into a research branch which becomes more and more promising. Some of the new proposals are:



The SunTower SPS concept, assumed 1000W/kg of specific power, while the thin-film based European Sail Tower SPS concept assumed 3500W/kg global specific power (including sail deployment mechanism, 4850W/kg if only taking the sail into account) with 13% efficiency CIS deposited on 7.5µm thick Kapton ® foils. [3]

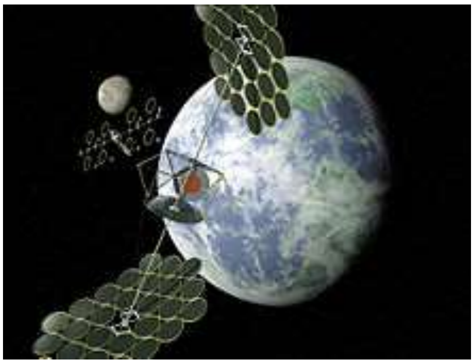
Fully deployed solar sail picture taken by the self–operating camera released by IKAROS (left) and one of the four petals of the solar sail with integrated a-Si solar cells in the center and reflectance control devices for the attitude control near the edges (right).
[Source: Wikipedia.en/Ikaros]



Vacuum deployment of a 20m x 20m solar sail made of CP1TM polyimide and CFRP masts in the NASA 30m Plum Brook Facility (courtesy of NASA, SRS, ATK-Ab). [3]

ISS Solar Array
Each of the 8 ISS solar array wings (often abbreviated "SAW") consists of two retractable "blankets" of solar cells with a mast between them. Each wing is the largest ever deployed in space, weighing over 2,400 pounds and using nearly 33,000 solar arrays, each measuring 8-cm square with 4,100 diodes. Each SAW is capable of generating nearly 31 Kilowatts (kW) of direct current power. When retracted, each wing folds into a solar array blanket box just 51 cm (20 in) high and 4.57 m (15.0 ft) in length.
[Wikipedia.en and 3]

Artist's concept of a solar power satellite in place. Shown is the assembly of a microwave transmission antenna on the left. The solar power satellite was to be located in a geosynchronous orbit, 35,786 kilometers (22,236 mi) above the Earth's surface (NASA 1976). [2]



SERT Integrated Symmetrical Concentrator SPS concept (NASA), consisting of two symmetrical ultra lightweight arrays of "SolarSailType" solar concentrator mirrors in a space-frame structure (symmetrical mirror arrays shown on-top and bottom of the image).
Fixed geometry between photo voltaic (PV) arrays and transmitter to minimize Power Management And Distribution (PMAD)/mass (middle section) and employing arrays of multi bandgap PV [2& https://space.nss.org/wp-content/uploads/Space-Manufacturing-conference-13-077-NASA-SERT-Program.pdf]

Wireless Power Transmission Technologies

Non-mechanical laser beam steering transmitting power down to Earth requires high accuracy steering capability. While the technology is well developed for microwave frequencies by using retrodirective antenna systems, non-mechanical beam steering of laser beams is still in its infancy. Two alternatives exist: mechanical and non-mechanical laser beam steering. Mechanical beam steering using piezoelectric and electromagnetic actuators has already been used for optical laser telecommunications. In 2001, inter-satellite optical data transmission demonstration achieved pointing accuracy of the order of 1µrad between the Artemis spacecraft (ESA) in GEO and SPOT-4 (CNES) in LEO using the SILEX payloads.

NASA Research [4]

In a presentation at the National Space Society’s International Space Development Conference May 27, 2022, Nikolai Joseph of NASA’s Office of Technology, Policy and Strategy said the agency was beginning a short-term study evaluating the prospects of space-based solar power, or SBSP, the first by the agency in about two decades.
“As the technology has evolved, the feasibility of the system has changed over time,” he said. “This study is going to assess the degree to which NASA should support space-based solar power.”
The study will not attempt to come up with a new architecture for SBSP, but instead reexamine past concepts for collecting solar energy in space and transmitting it to the ground for conversion to electricity. Those updated systems will be compared to terrestrial power systems and assess policy and implementation challenges they face.

Conclusion

In view of the current energy crises and climate change attempts ESA and also NASA revived the space based energy supply research in 2022 picking up on Oberth’s idea in earnest.

References:

[1]https://www.esa.int/Enabling_Support/Preparing_for_the_Future/Discovery_and_Preparation/ESA_reignites_space-based_solar_power_research

[2] https://en.wikipedia.org/wiki/Space-based_solar_power

[3] IAC-11-C3.1.3 PROSPECTS FOR SPACE SOLAR POWER IN EUROPE Leopold Summerer European Space Agency, Advanced Concepts Team, The Netherlands, Leopold.Summerer@esa.int

[4] https://spacenews.com/nasa-to-reexamine-space-based-solar-power/

July 2022, Joachim J. Kehr, Editor Journal of Space Operations & Communicator
https://opsjournal.org