Space-Based Solar Power

A reliable solution to help decarbonize Europe?

Hands-on strategy
& competitive solutions

2023

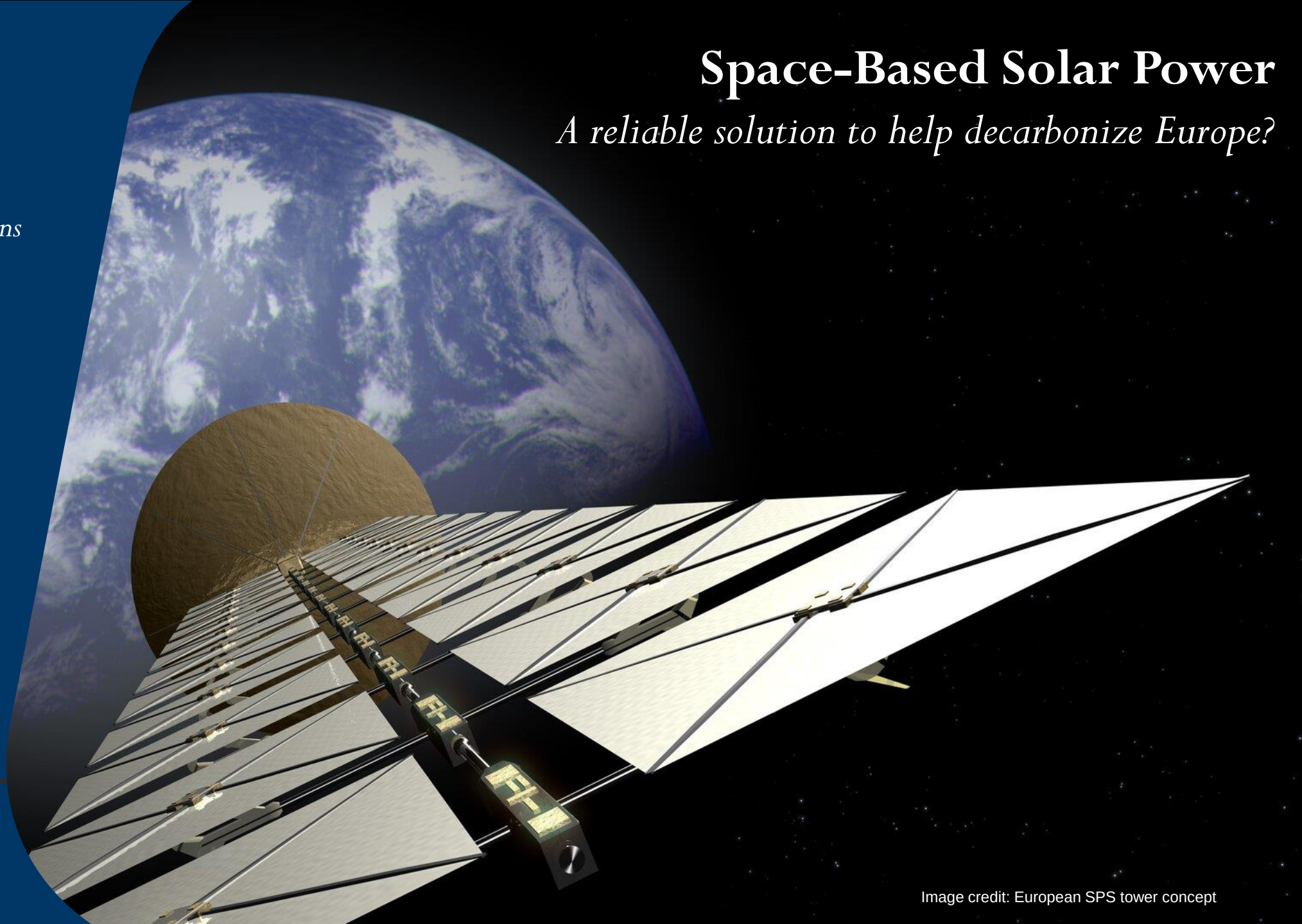


Image credit: European SPS tower concept

Technological innovation, public-private partnerships and commercial viability allow the development of Space-Based Solar Power (SBSP)

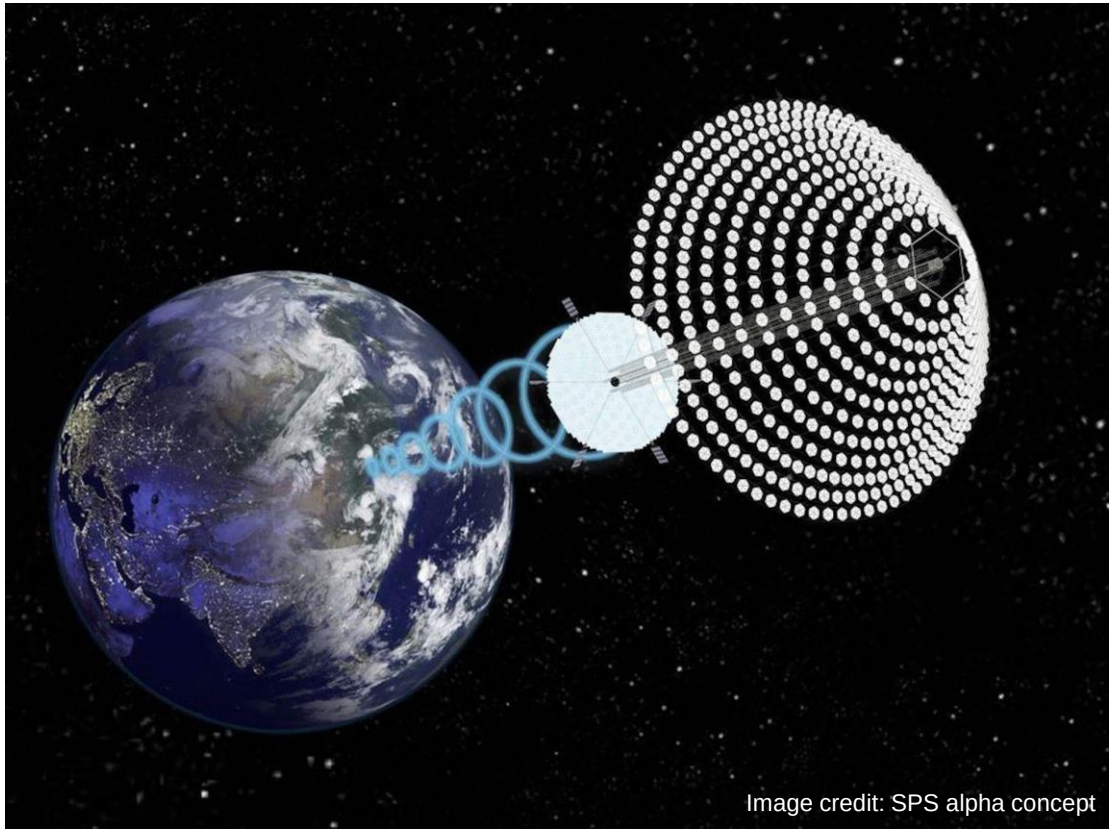


Image credit: SPS alpha concept

The Case for SBSP

- SBSP provides a **reliable, renewable** and **limitless energy supply**, unaffected by weather or daylight limitations.
- SBSP could be a **solution** to **climate change** and **European needs** for sustainable energy, and exploring its feasibility is crucial for a sustainable future.

Key industry trends

Technological advancements

Latest innovation in solar cell technology, materials, robotics and on-orbit assembly and maintenance

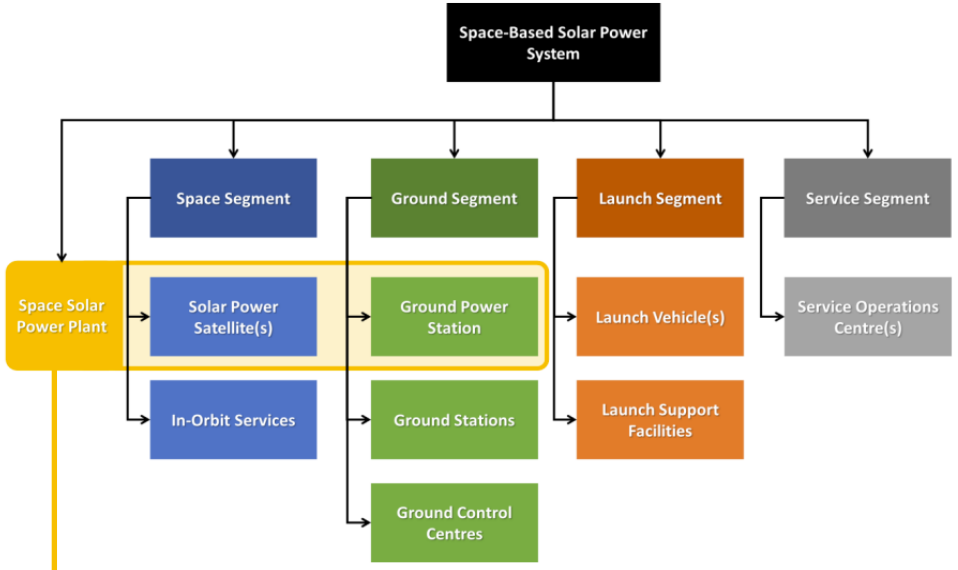
Public-Private partnerships

Governments, space agencies, and private companies are building partnerships and consortiums to invest in SBSP R&D

Commercial viability

With decreasing costs of solar energy, SBSP is becoming more and more commercially viable

Major SBSP technical challenges are concentrated in the Space Solar Power Plant



Space Solar Power Plant Key elements

Thermal material and management system (TMS)

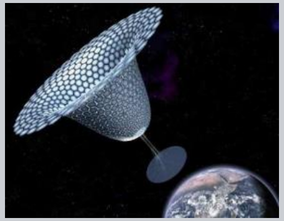
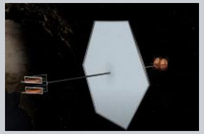
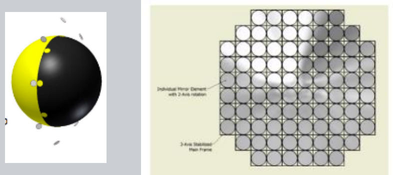
Optional: Reflectors	Solar panels	Power management and distribution system (PMAD)	Wireless power transmission system (WPT)	Ground power station

Technology:
- Concentrators photovoltaics (CPV): Si or GaAs
- Multi-junction cells

Technology:
- Radio frequency waves (microwave)
- Laser (less efficient but smaller transmission apparatuses)

Sources:
[1] OHB TN 01 Cost vs. benefits studies, ESA - Cost vs. benefits studies
[2] ESA Statement of Work, Pre-Phase A System Study of a Commercial-Scale Space-Based Solar Power (SBSP) System for Terrestrial Needs
[3] Shubham Gosavi, A Review on Space Based Solar Power, 2021, (PDF) A Review on Space Based Solar Power (researchgate.net)

5 main projects falling into 4 categories have been disclosed so far

Category	Electrical power over articulated joint(s)	Optical power over articulated joint(s)	Fixed structure	Solar refractors (no energy conversion)	
Project	 Mr SPS	 SPS Alpha	 CASSIOPeiA	 Project Solspace	 Mirasolar (18 satellites constellation)
Concept	WPT pointing a fix point on Earth	WPT pointing a fix point on Earth	Fixed sun-pointing mirrors	Mirrors steered using rotating flywheels	3 axis Stabilized Main frame with 2 axis tracking individual mirror targeting earth station
Energy transmission to Wireless power transmission (WPT)	Electrical transmission	Optical transmission	Optical transmission	No WPT	No WPT
Reflectors	No reflectors	Individually heliostats mirrors	Fixed mirrors	Mirrors steered using rotating flywheels	2-axis Individually earth tracking mirrors
Solar Panels	Concentrator photovoltaics (CPV) Thin-film GaAs	CPV multi-bandgap architecture with integrated thermal management	CPV Fresnel-Kohler concentrator	No PV	No PV
WPT	Retro-directive planar Radio frequency (RF) phase-array	Retro-directive planar RF phase-array	Retro-directive helical RF phased array	No WPT	No WPT
Power delivered[1]	1 GW for 11 800 m of wingspan	2 GW	2 GW for 1700 m of wingspan	144 MW per Satellite	5,5 GW for 10 km of diameter
Cost estimated[2]	$30B for 1 GW	$31B for 2GW	$35B for 1GW	-	$11B[3]
Trade-off	Concentration and long distribution power path requiring special consideration of losses and thermal dissipation.	Concentration of power requiring special consideration of losses and thermal dissipation	Reliability	Work with current solar panel fields	Work with current solar panel fields

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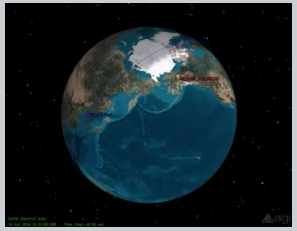
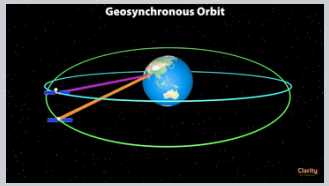
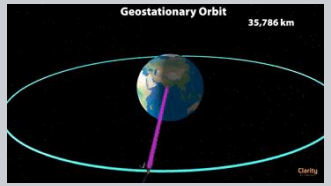
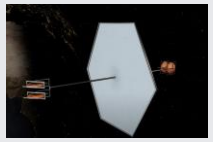
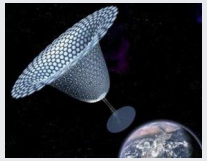
1- DC ground receiver output
2- In-space total transportation cost assumptions: Mr SPS: 1000$/kg, SPS Alpha: $ 500/kg, CASSIOPeiA: 1000$/kg, Mirasolar: 400$/kg

Sources:
[1] Xinbin, H. Space Solar Power development in China and MR-SPS, 2015 蟷ｿ髱ｯ迚・1 (sspss.jp)
[2] Xinbin, H. Multi-Rotary Joints SPS,2015. Multi-Rotary Joints SPS (ohio.edu)
[3] John C. Mankins, SPS-ALPHA: The First Practical Solar Power Satellite via Arbitrarily Large Phased Array, 2012. SPS-Alpha: The first practical solar power satellite via arbitrarily large phased array (nasa.gov)
[4] Ian Cash, CASSIOPeiA – A new paradigm for space solar power, 2019. CASSIOPeiA – A new paradigm for space solar power (spaceenergyinitiative.org.uk)
[5] Ian Cash, IECL CASSIOPeiA Solar Power Satellite Presentation ISDC 2018 [Vidéo], IECL CASSIOPeiA Solar Power Satellite Presentation ISDC 2018 – YouTube
[6] Professor Colin McInnes, ENHANCING SOLAR POWER GENERATION FROM SPACE, University of Glasgow - Explore - Sustainability at Glasgow - Research - Enhancing solar power generation from space
[7] Lewis M Fraas , Mirrors in Space for Low-Cost Terrestrial Solar Electric Power at Night, National Space Society |https://space.nss.org/wp-content/uploads/Mirrors-in-Space-for-Electric-Power-at-Night-2012.pdf

The main SBSP projects choose SSO, GSO and GEO orbits

	Polar orbit and Sun-synchronous orbit (SSO)		Geosynchronous orbit (GSO)		Geostationary orbit (GEO)
					
Project					
	Project Solspace	**Mirasolar**	**SPS Alpha[1]**	**CASSIOPeiA[2]**	**Mr SPS**
Altitude	200 -1000 km		35 786 km		35 786 km
Interest	SSO is above a point on the Earth constantly at the same time of the day		Constantly stay above the same region on Earth		Constantly stay above the same point on Earth
Utilization	• Imaging satellites • Weather monitoring satellites		• Telecommunication satellites • Weather monitoring satellites		• Telecommunication satellites • Weather monitoring satellites

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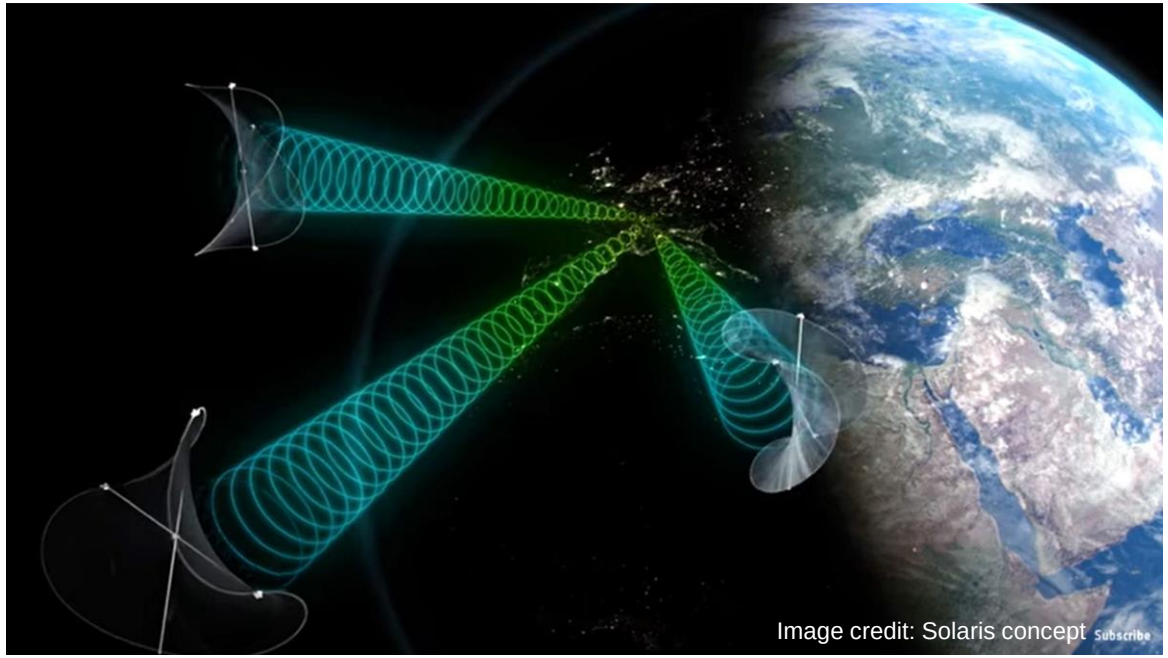
1 - SPS-ALPHA might also be based in alternative Earth orbits, or elsewhere, such as at Earth-Moon Libration points, lunar orbit, Sun-Earth Libration points, Mars orbit
2 – CASSIOPeiA could be also used for GEO, Medium earth orbits (MEO) with 4 satellites, Elipitcal sun-synchronous orbits with 5 satellites, Low earth orbits (LEO)

Sources:
[1] Types of orbits, The European space agency, ESA - Types of orbits
[2] Clarity of Concept. (2021, 2 juillet). Geostationary vs Geosynchronous vs Polar Orbits : UPSC [Vidéo]. YouTube. https://www.youtube.com/watch?v=H-gaSnxP60A

What's next? Solaris ESA preparatory program for launching a commercial-scale SBSP in 2040

- **ESA** has launched **SOLARIS**, a preparatory initiative for future decision making on European SBSP.
- **SOLARIS** aims to establish the **viability** of Space-Based Solar Power for clean energy needs on Earth, potentially leading to a **full development program** decision in **2025**.
- The initiative has set targets for launching a **sub-scale demonstrator** by **2030**, a **pilot SBSP** by **2035**, and **commercial-scale SBSP** by **2040**.



From a promising concept to a European commercial-scale SBSP in 2040

Why is SBSP a promising concept?

- SBSP can help Europe sustaining the **growth** of **non-dispatchable renewable energies** by providing **reliable**, **renewable** and **limitless** energy supply

Key trends

- **Technological innovation**, **public-private partnerships** and **commercial viability** allow the development of SBSP concept.

Next challenges

- Key SBSP technologies (wireless power transmission system, on-orbit assembly and maintenance) are still in their **early stages** of **development** for size scale required by SBSP
- Their **maturity process** will affect the performance and therefore the cost competitiveness of SBSPs and create **uncertainty** around the commercial viability of SBSP.

How will Europe handle these challenges?

- ESA recently launched **Solaris** program that will help Europe to go from 0 to 1 and build their own commercial SBSP by **2050**.

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