SOLARIS: ESA R&D into Space-Based Solar Power

SOLARIS Industry Day, ESTEC
18 Oct 2022


We have an
Urgent Energy
Problem
Climate Crisis
Energy Security

Existing energy options have **major challenges** to meet Net Zero goals

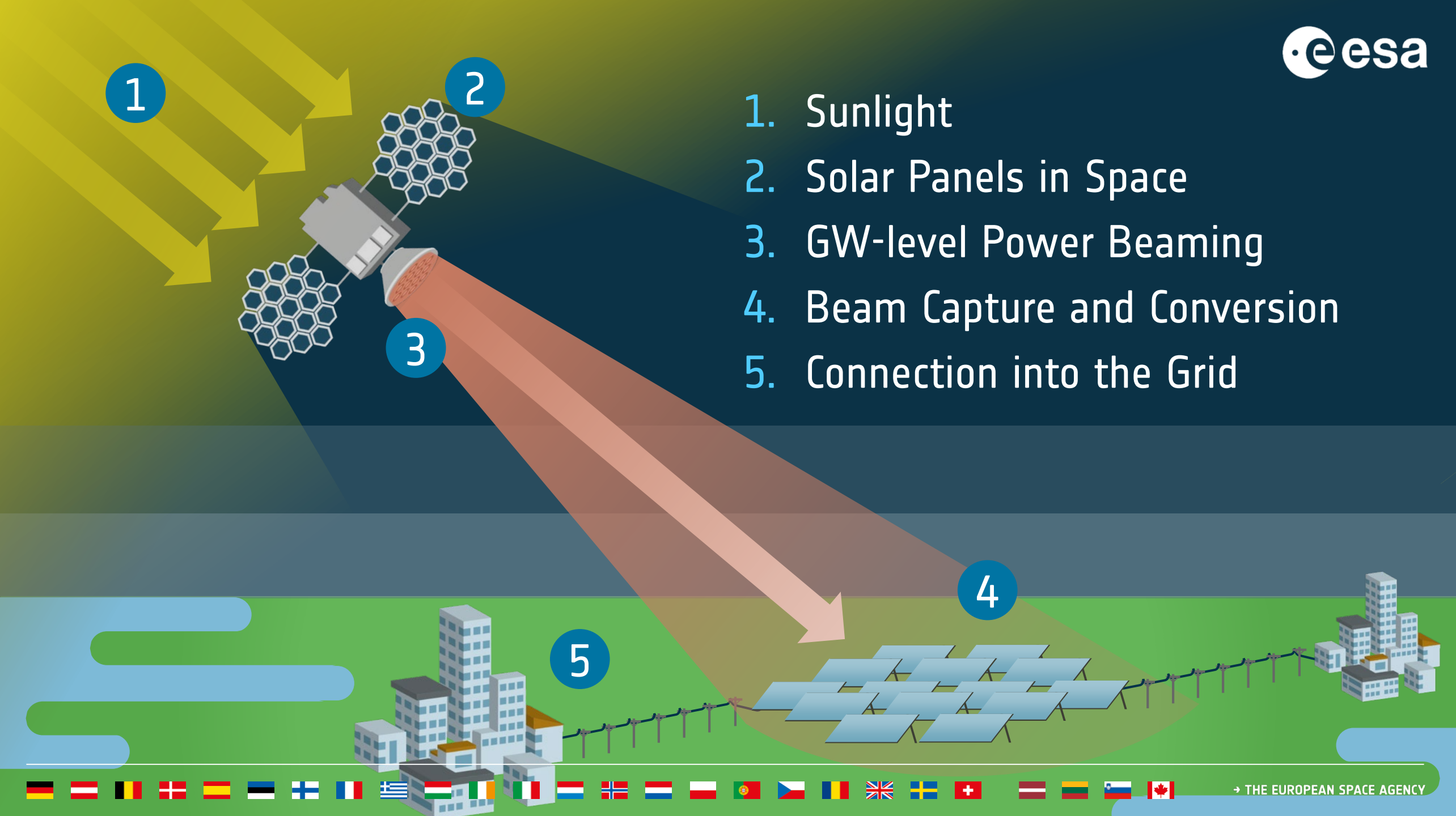
Scalability? **Availability?** **Land Use?**

Space-Based Solar Power (SBSP)

Delivers solar energy from space to Earth

Benefits: Baseload, **scalable, clean, secure** and available **anywhere in the world**

Timely: Urgency for decarbonisation of energy
Falling launch and hardware costs
Advancement of space technologies
Opportunity for European leadership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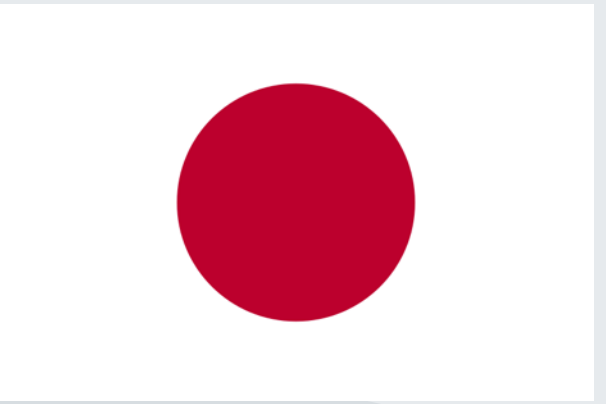
1. Sunlight
2. Solar Panels in Space
3. GW-level Power Beaming
4. Beam Capture and Conversion
5. Connection into the Grid
→ THE EUROPEAN SPACE AGENCY

SBSP is already being developed around the world

- US Navy did space tests (2020) and Air Force planning space-ground tests in 2024
- 100's M$ being invested through DOD and private investors

- 10's kW-scale demonstrator planned for 2028
- GW commercial plant by 2050
- SBSP ground station & test facilities already being developed



- Long-term technology programme in JAXA (Basic Space Policy)
- SBSP solar panel demonstration on ISS planned for 2023

ESA Cost-benefit Study of SBSP for terrestrial energy needs (Feb ‘22 - Aug ‘22)

Study objective:

to perform a costs and benefits analysis of SBSP to provide ESA and its Member States with the necessary technical and programmatic information regarding the potential for space-based solar power energy generation to provide environmentally sustainable, affordable clean energy to Europe to meet its growing future energy needs and its Net Zero by 2050 goal

Full results available at:
https://www.esa.int/Enabling_Support/Space_Engineering_Technology/SOLARIS/Cost_vs._benefits_studies

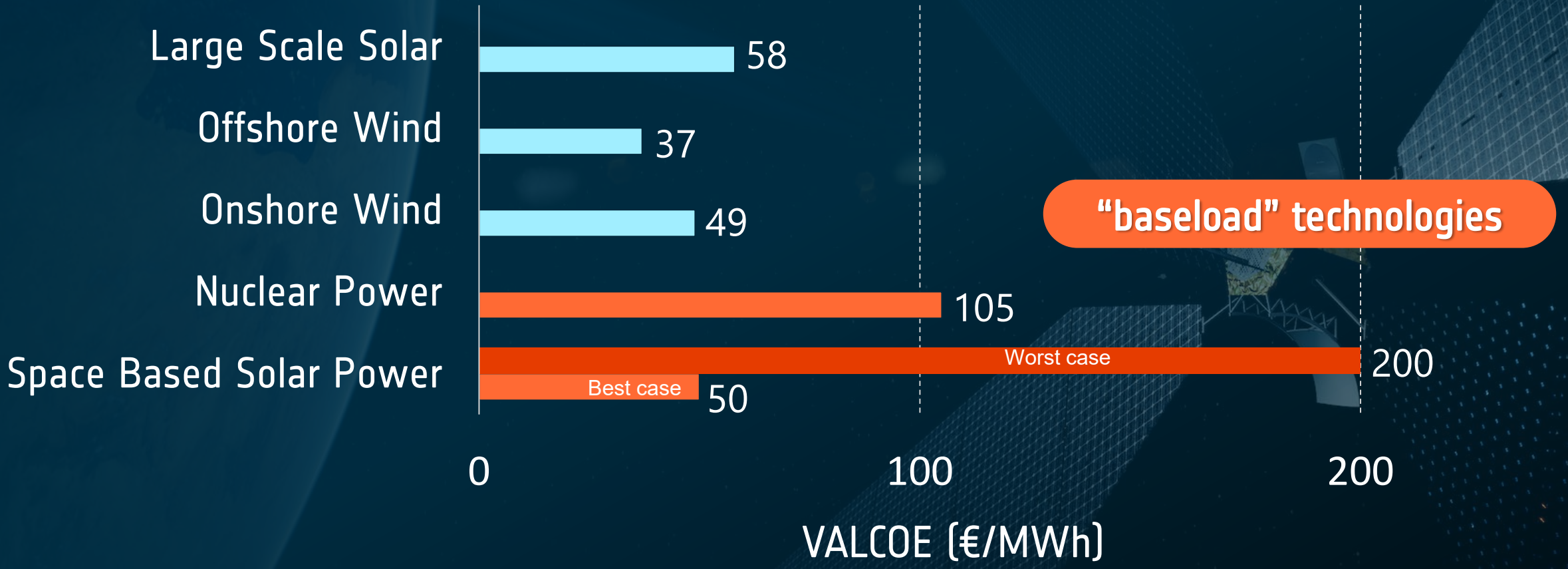
ENGINEERING AND DEVELOPMENT CHALLENGES

System element	Description	Time to development (indicative)
Reflector system	Array of reflector units mechanically connected with associated sub-elements such as pointing mechanisms and wireless communication systems	2–5 YEARS
Connecting boom	Structural connection between the reflector system and energy conversion system	5–10 YEARS
Energy conversion system	Converts sunlight to radio frequency – includes sub-elements such as antennas and associated thermal management systems	10–20 YEARS
Attitude control system	Controls the attitude and position of SBSP thanks to onboard hardware and software	5–10 YEARS
Backbone data-handling network	Hardware architecture for very large wireless networks with core processing units and wireless terminals for 2,000,000+ clients	5–10 YEARS
Network control software	Software architecture for very large wireless networks for 2,000,000+ clients	5–10 YEARS
Communication to the ground	Telemetry, tracking and control (TT&C) systems onboard the space platform	READY AND AVAILABLE
On-orbit assembly and maintenance	Robotic arms to enable robotic operations and associated sub-elements such as batteries, charging stations and storage units	10–20 YEARS
Space debris mitigation system	In-orbit space situational awareness (SSA) systems with collision-avoidance capabilities to prevent impacts with human-made or natural debris	5–10 YEARS

Subsystem element			TRL	Development Degree of Difficulty
Core Power Systems				
	Satellite			
		Satellite collect	5	High
		Satellite convert	2	High
		Satellite transmit	4	Very High
		Satellite structure	3	Very High
		Satellite thermal management	3	High
		Satellite control system	4	Medium
		Satellite station keeping	3	High
		Satellite communications	6	Low
	Ground Station			
		Ground receive	4	High
		Ground convert	7	Low
		Ground distribute	7	Low
		Ground grid connection	8	Very Low
		Ground structure	7	Low
		Ground control system	6	Medium
		Ground operations: Power Control Interface	8	Low
		Satellite operation: Mission Control Interface	4	High
		Ground communications	4	Medium
Enabling Systems				
	Satellite			
		Spacelift	7	High
		Satellite manufacture (ground)	6	Low
		In-orbit assembly	3	Very High
		In-orbit maintenance	3	Very High
		Decommission satellite	2	Very High
	Ground Stations			
		Rectenna manufacture	4	Medium
		Power station construction	8	Very Low
		Operation station construction	8	Very Low
		Maintenance of ground stations	7	Very Low
		Decommission ground stations	8	Very Low

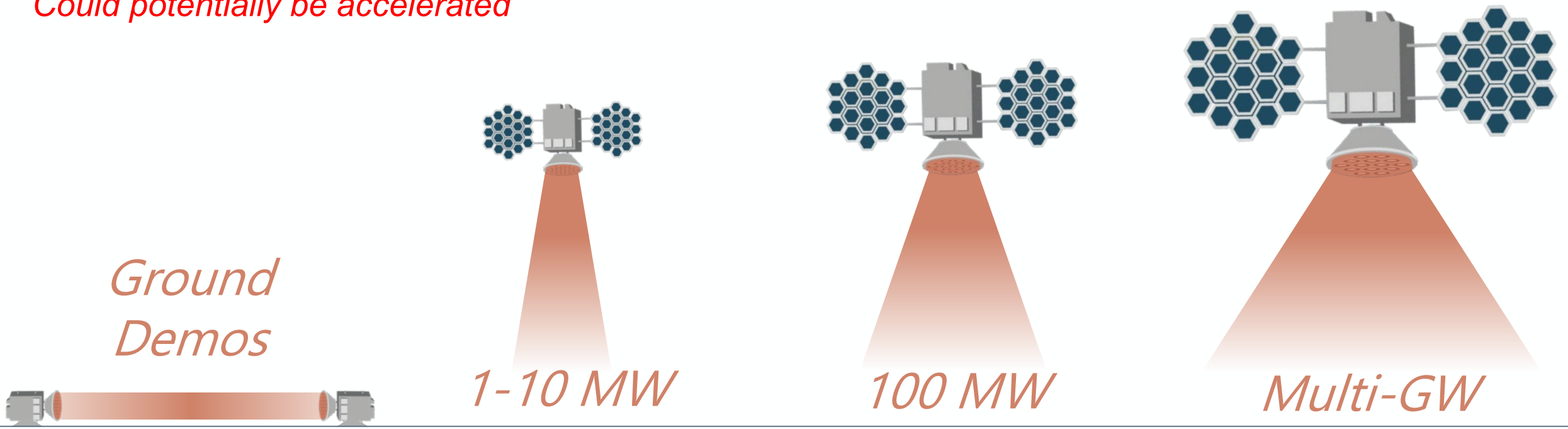
ESTIMATED ELECTRICITY COST

Projected Value adjusted Cost of Energy (VALCOE) in 2050 for Low Carbon Energy Generation (10th of a Kind SPS)



When could commercial SBSP be ready?

Could potentially be accelerated



2023-2025	2026-2030	2031-2035	2036-2040
SBSP preparatory programme	Sub-Scale Space-Based Demonstrator	Pilot Space-Based Power Station	Operational Space-Based Power Station

ESA COST-BENEFIT STUDIES - CONCLUSIONS

SBSP could provide competitively-priced electricity to European homes and businesses by 2040, displacing fossil-fuels and some nuclear, while complementing renewables like solar PV and wind, reducing the need for large-scale storage solutions.

When deployed at scale (25-50 SPSs by 2050), SBSP would provide substantial environmental, economic, and strategic benefits for Europe, including energy security.

A lot of challenging technology developments are needed to be matured and these will have widespread applications both on Earth and in space.

Awareness raising, especially amongst the energy sector and public authorities, and further investments in technology R&D, are needed now.

Objectives for SOLARIS (2023-25)

Determine **benefits, technical feasibility, costs** and **risk**

Raise awareness of SBSP amongst key stakeholders

Establish opportunities for international cooperation

Prepare **proposal for a development programme**

Position Europe as a **serious player in SBSP**

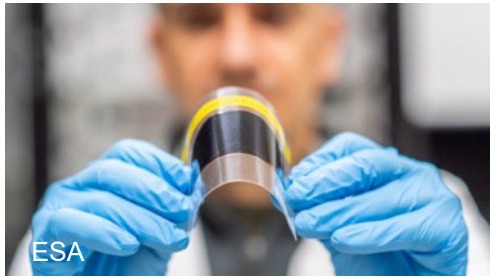
SOLARIS proposed R&D activities (2023 – 2025)

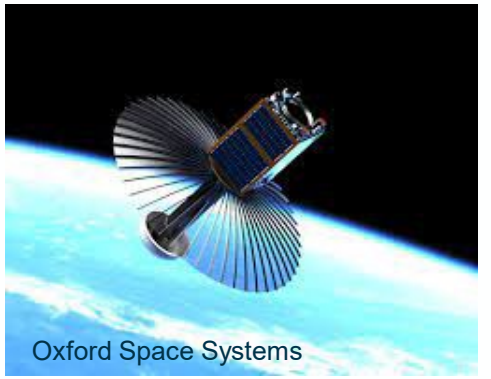
System Studies for Commercial-scale Space-based Solar Power System (Phase 0)
System studies up to Phase B1 for a flight demonstrator mission
Technology maturation
High mass-efficiency solar PV conversion
High-efficiency RF generation and accurate beam forming
High power management and distribution
Large scale structures deployment, in-space manufacturing, robotic assembly and maintenance
Ground/aerial demonstrators of power beaming and reception
Environmental, health & safety studies & testing
Stakeholder engagement and communication

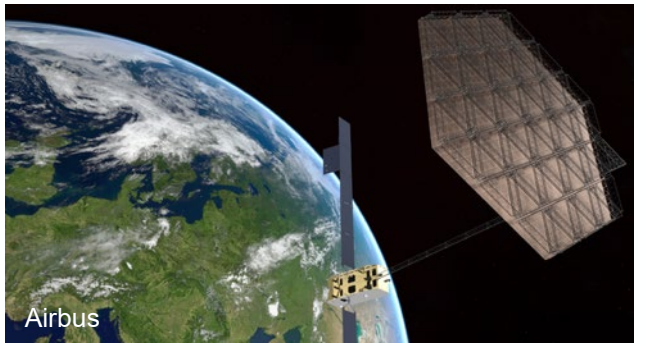
To be supported by D/STS Future Launchers Preparatory Programme for Reusable Heavy Lift Launcher studies

Synergies of SOLARIS Technology Activities with other space and non-space activities

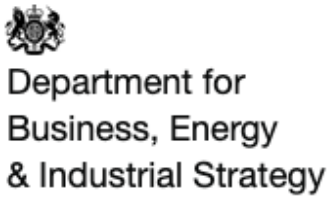
- Lightweight, compact, efficient, cost effective, space compatible solar cells and solar generators => benefits in all space applications
- High voltage power management architecture and components => direct application in Telecommunication satellites and Exploration spacecraft
- Large antennas beyond state-of-the-art => direct application in Telecommunication satellites
- On-orbit assembly, manufacturing and modelling of large structures in space => applicability to large spacecraft structures (e.g. solar arrays, antenna structures, radiators, telescopes, interferometers) for enhanced spacecraft performance and mission return







Stakeholder engagement



Takeaways:

- Value and Urgency of SBSP benefits recognized
- High Investment potential in case of institutional backing

Take-home messages

1. Independent ESA-funded studies suggest that Space-based Solar Power has the potential to contribute **clean** and **secure energy** for a **Net Zero future**.

2. The are many challenges and in order to fully understand its credibility, substantial R&D activities are required now => **ESA's SOLARIS initiative** is a proposal @ CM22 to address this **to prepare future decisions**.

3. Participation in SOLARIS would allow industry and academia to **participate** in the development of key technologies for SBSP, which will also have **broad applications for both space and terrestrial markets**.

www.esa.int/SOLARIS