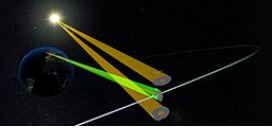
Space Based Solar Power (SBSP) Innovation Programme

Stakeholder Engagement

Wednesday 30 March 2022

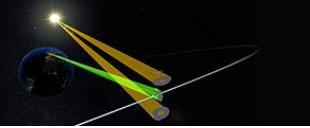


Welcome & Content

Description	Organisation
Welcome	Frazer-Nash
Programme Overview	BEIS
Overview of SBSP	Frazer-Nash
Technical Questions and Answer Session	Frazer-Nash
Wireless Power Transmission	All
Photovoltaics	All
Systems Engineering	All
Close	

Space Based Solar Power

Programme Overview



Background

Net Zero Challenge

- High renewables
- Reliable and balanced energy system

SBSP Feasibility Study

- BEIS/UKSA
- Technical and economic feasibility
- Literature review
- Industry workshops
- International expert consultation

Expression of Interest

- Following the publication of study - October 2021

Stakeholder Workshop

- Competition preliminary info
- Views on innovation needs
- Opportunity to network

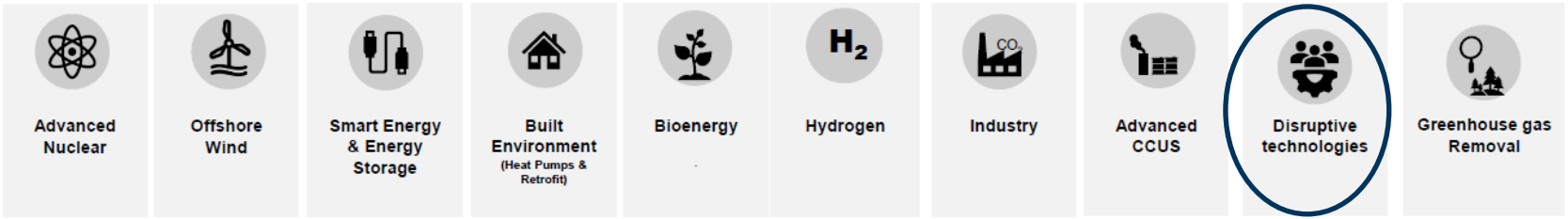
Analysis report: https://www.gov.uk/government/publications/space-based-solar-power-de-risking-the-pathway-to-net-zero

Net Zero Innovation Portfolio (NZIP)

PM's 10 Point Plan for a Green Industrial Revolution

- Point 10: Green Finance and Innovation - unleashing innovation and developing new sources of finance
- £1 billion Net Zero Innovation Portfolio – to accelerate the commercialisation of innovative low-carbon technologies, systems and processes in the power, buildings and industrial sectors

NZIP Priority Areas



Programme Objectives

£3m research & development grant funding for key component technologies for space based solar power with spin-off applications in terrestrial settings

Increase in TRL level

UK leadership in clear energy sectors

UK leadership in international SBSP community

Dissemination to international stakeholders, industry and academia

Stimulate further innovation that that may benefit other clean energy sectors

Technology Scope

Lot 1: Wireless Power Transmission - *£1.25m*

Development of high power wireless electromagnetic power transmission system with high efficiency and directionality over a long range beyond the state-of-the-art

Lot 2: High Concentration Solar Photovoltaics - *£1.25m*

Development of innovative solar cells including new system design and novel materials research to increase its efficiency and reduce cost

Lot 3: Systems Engineering - *£500k*

Systems studies, management, design, and integration of wireless power transmission and high concentration solar PV

Eligibility Criteria

Innovation and technological readiness

TRL 1 - 6

Project status

Unable to fund retrospective work

Subsidy Control

Match funding required

Cumulative public subsidy applies

Project location

Over 50% of project costs must be incurred in the UK

Project duration

Must be completed before March 2025

Maximum allowable funding

£1m per project and £2.5m per single applicant

Delivering multiple projects

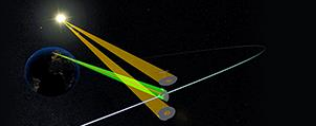
Lead applicant can submit more than one bid

One application per lead in each Lot

General Conditions

Companies of any size are eligible to seek funding

Standard BEIS T&Cs



Assessment Criteria

Criterion	Weighting
Technical concept and level of innovation	20%
Credibility of technical approach; relevance to the development of SBSP; relevance to Net Zero	20%
Dissemination strategy	10%
Project plans, risks and management	15%
Project costs and value for money	20%
Project skills and experience	15%

Minimum score of 60% to be eligible for funding

Programme Timeline

Application

- Competition Launch - May/June 2022 (8 weeks)
- Q&A published (2 weeks after application opens)

Assessment

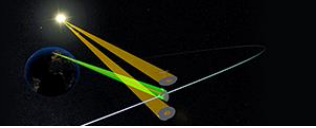
- BEIS and third party assessors - September 2022

Award

- Notification – October 2022
- Grant awards – November 2022

Space Based Solar Power as a Contributor to Net Zero
A Techno-economic study into Space Based Solar Power

Overview of SBSP



Project Aim:

To develop a credible evidence base to justify further work into developing SBSP as a contributor to the UK's Net Zero target.

Two phase project:
Phase 1 – Review of the engineering feasibility of SBSP.
Phase 2 - Assessment of the cost and wider economic benefits of SBSP specific to the UK

Considered SBSP in the context of UK sovereign, base load, GW scale energy generation.
Political, legal, regulatory and environmental impacts were not explored.

Results delivered April 2021

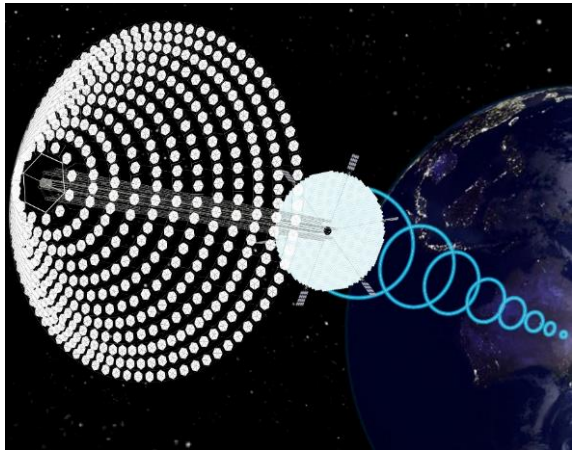
Phase 1 – Engineering feasibility of SBSP

- Investigate available SBSP designs and costs
- Explore the engineering barriers in delivering SBSP
- Assess the contribution SBSP could make to UK Net-Zero target
- Provide a technology roadmap for the Development of SBSP

Phase 2 – Cost and economic benefits to the UK

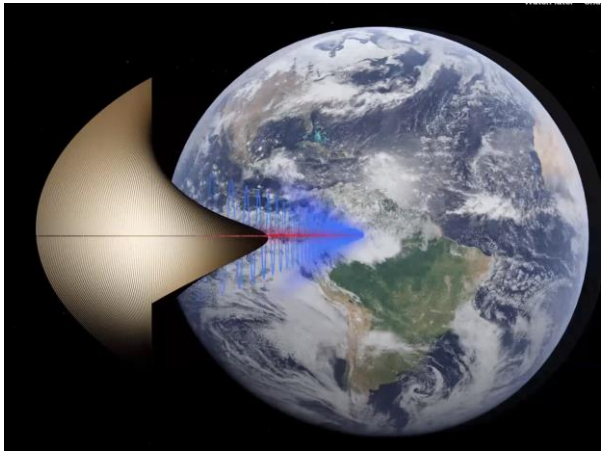
- Develop a cost model
- Assess the cost benefit of SBSP
- Identify the potential for spill-over benefits from the technology development
- Assess the ability of the UK to deliver the solution
- Assess the level of private and public funding needed

Reviewed 3 leading base load Solar Power Satellite concepts



SPS Alpha
John Mankins, USA

Multi-Rotating Joints SPS
Xinbin Hou, CAST, China

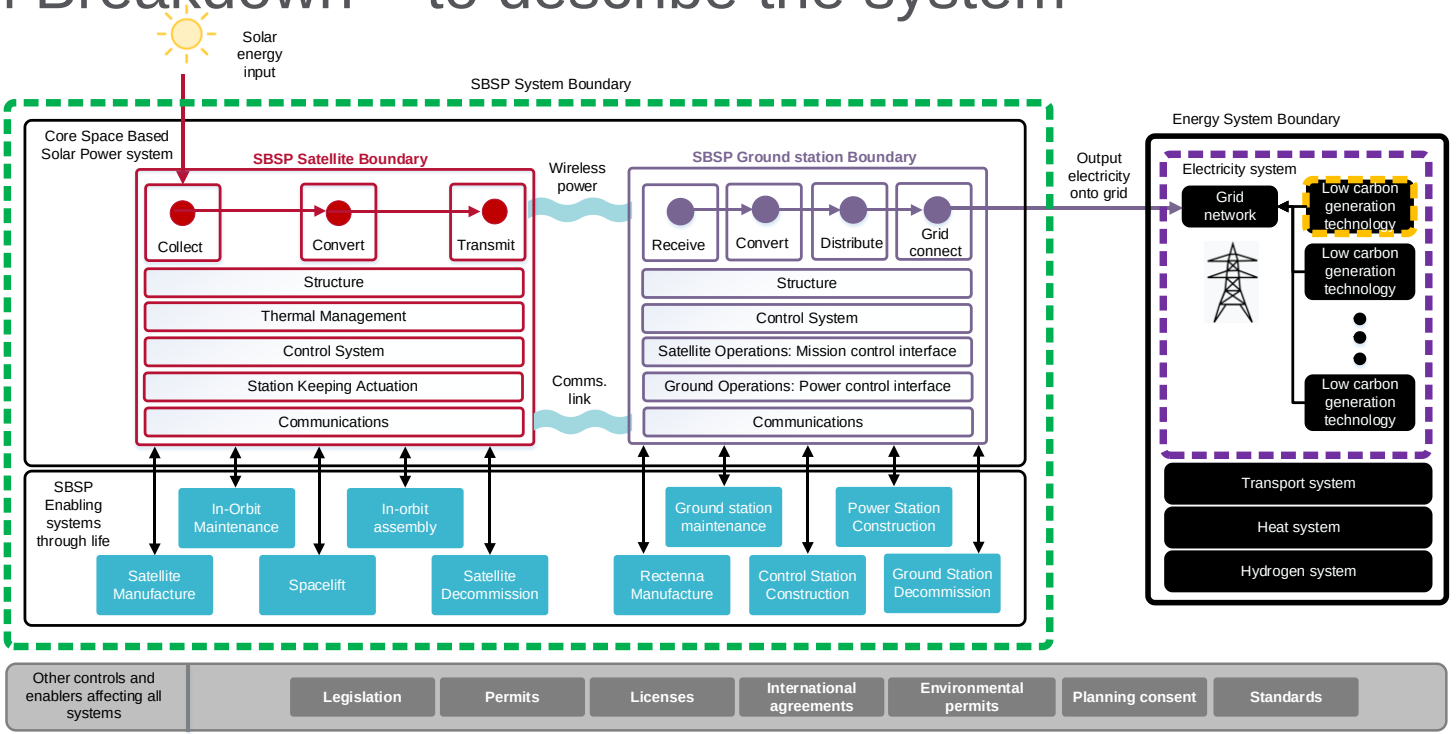


CASSIOPeiA
Ian Cash, IECL, UK

Assessment based on:

Five satellites, each satellite located in Geosynchronous Orbit providing 2 GW to the grid, Generating 10 GW total

System Breakdown – to describe the system



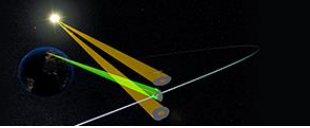
Phase 1 Engineering feasibility of SBSP - Conclusions

The study reviewed:

- The engineering barriers to be overcome
- The technological development required, and
- The roadmaps that are required in order to deliver sufficient SBSP capability by 2050.

The Study Concluded:

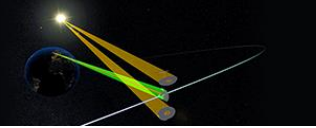
- The engineering development required to realise a 10GW SBSP capability in 2050 is feasible
- SBSP could contribute to the UK energy system and support Net Zero.



Phase 1 Engineering feasibility of SBSP - Conclusions

The key engineering barriers to achieving SBSP in order to support Net Zero in 2050 are:

- Technology maturation needed across all subsystems, in particular:
  - Decommissioning the satellite
  - Wireless Power Transmission
  - Reduce mass and increase efficiency of key systems eg PV
  - Satellite structural and control subsystems
  - In-orbit assembly and maintenance robotics
- Sufficient production facilities to manufacture the satellites.
- Sufficient launch capability to deliver the satellites to their operational orbits.



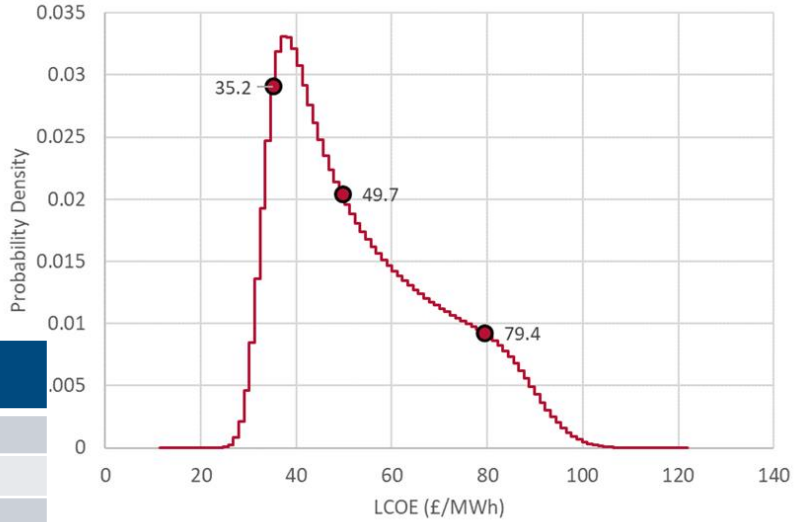
Phase 1 Engineering feasibility of SBSP - Conclusions

Additionally, a number of whole system engineering barriers were identified:

- Sufficient land area to deploy the rectennas.
- System security and debris damage withstand.
- There is a potential risk of material shortages for the manufacture of the solar photovoltaic panels.

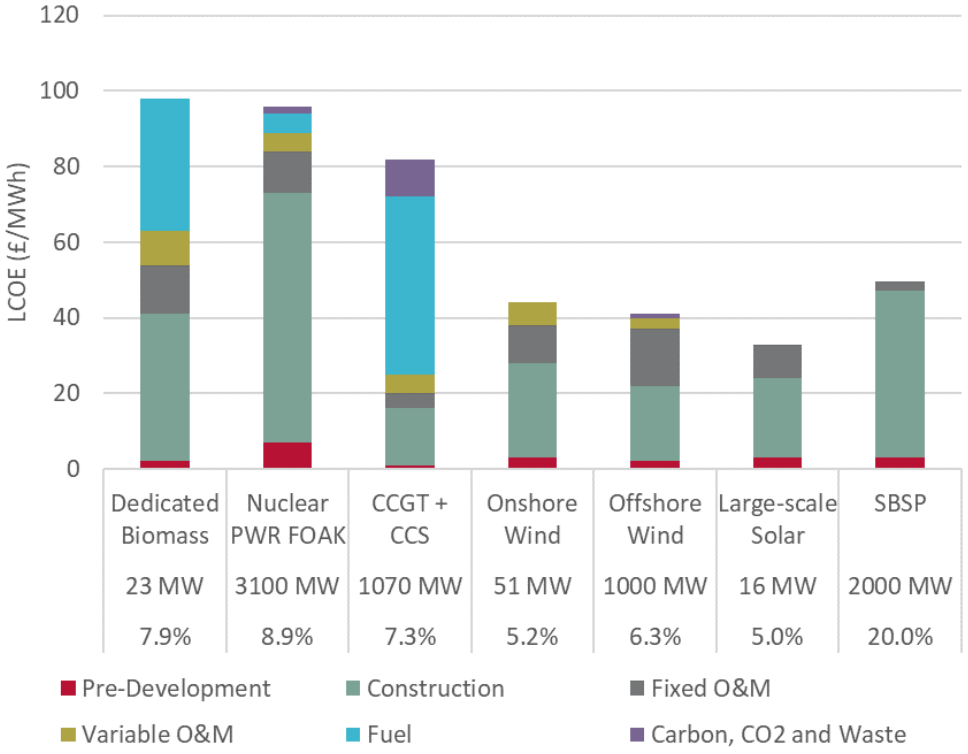
Cost Model

- Probabilistic cost model used to explore LCOE
- Input Data from referenced sources
- Sensitivity analysis for key cost drivers
- Output used to inform Economic Analysis



Scenario	Levelised Cost of Electricity (£/MWh)		
	p10	p50	p90
Baseline (20%)	35.2	49.7	79.4
Low Hurdle Rate (10%)	18.9	26.2	41.2
Reduced Hurdle Rate (15%)	26.7	37.4	59.4
High Hurdle Rate (25%)	43.6	63.2	100.9
High Spacelift Cost (£2,410/kg)	83.7	91.0	99.0
Low Spacelift Cost (£358/kg)	29.9	33.4	37.3
FOAK (first of a kind)	51.3	66.3	96.0
15 year life (20% hurdle rate)	37.3	50.9	81.0

LCOE comparison with other generation technologies



Costed Development Plan

2022 – 26
PHASE 1 – TRL 5
Ground based satellite demonstrator & balloon trials

Phase 1
- WPT performance parameters established
- Rectenna design established
- SPS architecture confirmed
- HCPV to RF conversion efficiency confirmed

2027 – 31
PHASE 2 – TRL 6
40MW SPS demonstrator in low earth orbit

Phase 2
- Meaningful power transmitted from orbit to earth
- Viability of SPS established
- SPS module sizes and configurations established
- Atmospheric effects on WPT investigated
- Assembly robots designed

2032 – 35
PHASE 3 – TRL 7
500 MW SPS demonstrator in operational orbit

Phase 3
- Autonomous in-orbit assembly demonstrated
- Packaging for space-lift optimised
- Reflector and structure optimised
- SPS and WPT control optimised
- SPS available for commercial power at end of tests

2036 – 39
PHASE 4 – TRL 8
2GW SPS Production prototype in operational orbit

Phase 4
- Full scale demonstration of the operational system
- Industrialisation of SPS manufacture complete
- Space launch capacity and providers in place
- SPS available for grid connection at end of tests

	Phase 1 TRL 5	Phase 2 TRL 6	Phase 3 TRL 7	Phase 4 TRL 8	Totals
	5 years	5 years	4 years	4 years	
p10	£125M	£530M	£2,410M	£7,925M	
p50	£135M	£575M	£2,675M	£9,965M	
p90	£145M	£620M	£2,930M	£12,610M	
NPV (p50)	£120M	£435M	£1,740M	£5,655M	£7,539M
NPV (p50) Including optimism Bias	£350M	£1,180M	£3,950M	£10,800M	£16,280M

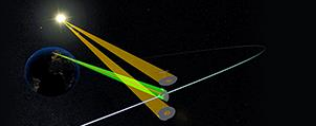
Phase 2 Cost and economic benefits to the UK - Conclusions

The study reviewed:

- The LCOE of SBSP and comparisons with other technologies
- The cost of a development programme
- The economic footprint of developing and operating a UK based SBSP system
- The spill-over benefits from the investment
- The level of public and private finding required
- A cost-benefit analysis
- Labour market assessment
- Contribution to UK strategic objectives
- Significant development and implementation risks

Phase 2 Cost and economic benefits to the UK - Conclusions

- Space Based Solar Power is technically feasible, and could be developed by 2040.
- It offers a new source of economically competitive baseload electricity.
- It requires a £16.3 billion development programme that could be achieved within 18 years.
- Public funding would be required for the majority of the development, given the substantial risk, cost and timescales.
- There are broader economic benefits for the UK to pursue the development of Space Based Solar Power, with a favourable GDP multiplier and benefit:cost ratio.

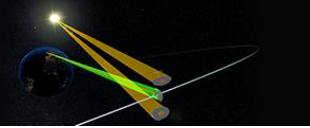


Phase 2 Cost and economic benefits to the UK - Conclusions

- The development could lead to substantial spill-over benefits.
- Development of Space Based Solar Power aligns well with a range of UK Government priorities.
- There are opportunities for international collaboration with our natural partners, and the UK is well placed to take a leadership role.

Space Based Solar Power

Technical Q&A Sessions



Technical Focus Discussions

Lot 1: Wireless Power Transmission

Development of high power wireless electromagnetic power transmission system with high efficiency and directionality over a long range beyond the state-of-the-art

EXPLORE

exploration of research gaps, challenges and promising areas

Why the R&D is novel or compelling (address the hardest / biggest challenges first)
What the R&D proposal would require
Who the R&D proposal would benefit

Technical Focus Discussions

Lot 2: High Concentration Solar Photovoltaics

Development of innovative solar cells including new system design and novel materials research to increase its efficiency and reduce

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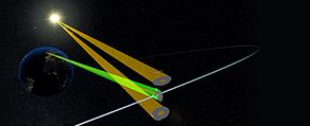

Technical Focus Discussions

Lot 3: Systems Engineering

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