An Investigation on the Challenges and Opportunities of SBSP and its potential in aiding the UK to achieve Net Zero

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Figure 1: SBSP Overview (ESA, 2022)

The Main Objectives

- To determine the potential of how SBSP can act as an enabler to the UK achieving net zero;

- To examine the technical and economic challenges and opportunities associated with SBSP;

- To evaluate how eco-design can help mitigate environmental impacts of SBSP.

Research Approach

A literature review was undertaken with information already available.

First-hand qualitative research carried out with 6 stakeholders within the SBSP industry – who took part in a semi-structured interview.

Key topic areas:

- The UK’s Net Zero Strategy
- Economic and Technical Feasibility of SBSP
- The Importance of Eco-design within SBSP

Currently

In an energy context:

- Over the next 30 years, the global demand for energy is set to double (Frazer-Nash Consultancy, 2019).
- The U.S Energy Information Administration (EIA) (2020), estimated that by 2050, global energy generation will increase to around 45 trillion kilowatt hours (kWh)

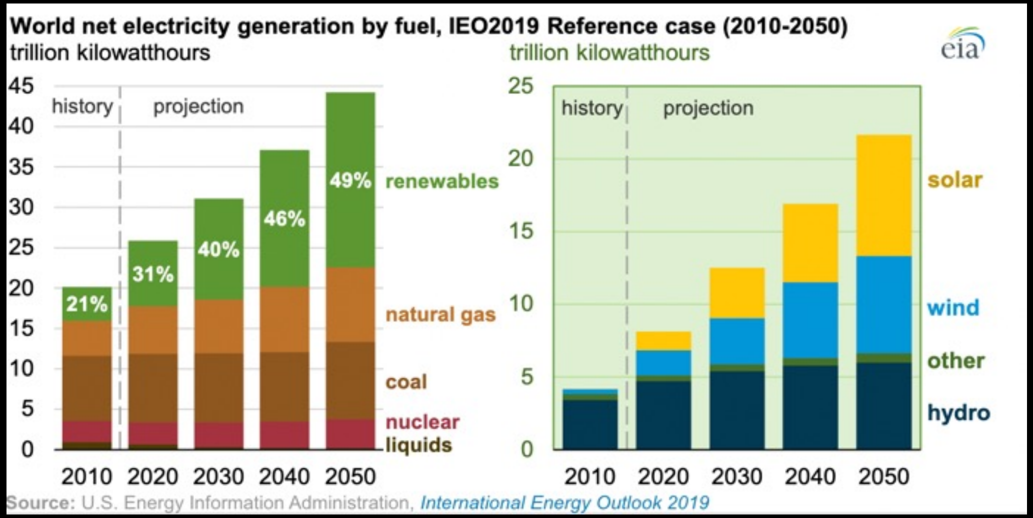


Figure 2: Global Energy Demand from 2010 to 2050 (EIA, 2020)

In a SBSP context:

- Eco-design is not a legal requirement during the design of SBSP systems.
- There are various technical and economic challenges for developing SBSP – however they have the potential to be overcome and help progress towards net zero.

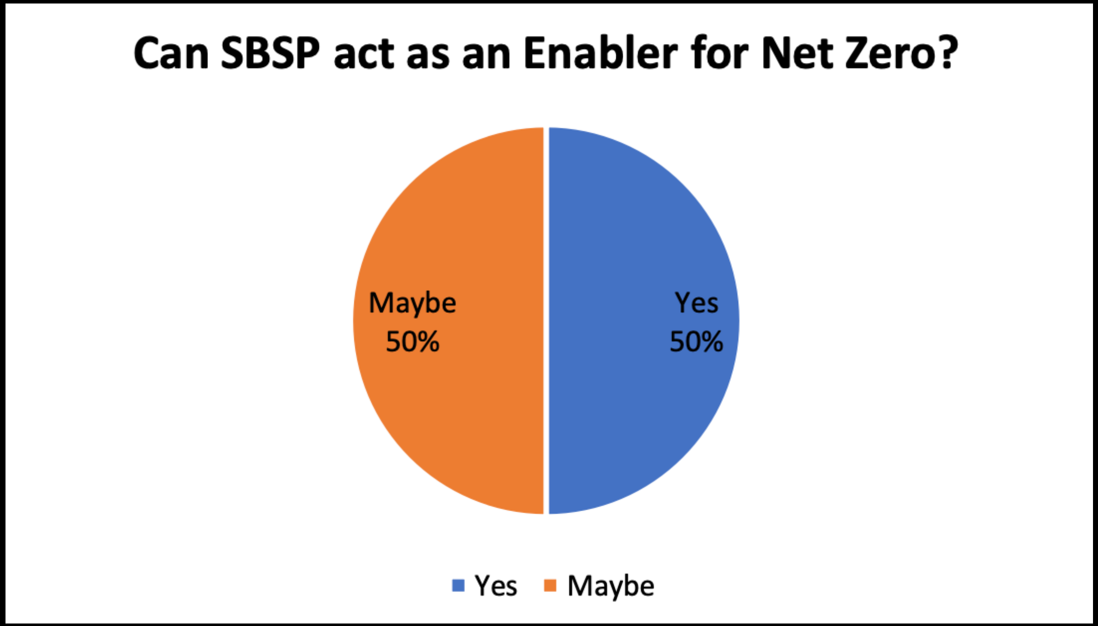
The UK's Net Zero Strategy

- Created in 2021
- Main goal: to reach net zero gas emissions by 2050 (HM Government, 2021)
- Space sector as a whole not mentioned

Primary Research Findings:

- Doubts casted on the capabilities of SBSP
- Despite this uncertainty, one off the participants stated:

"I think SBSP is one of the only ways to achieve Net Zero."



Technology Readiness Levels (TRLs)

A framework used to assess and communicate the maturity and readiness of a technology

A Phase 1: Engineering Feasibility Report was carried out by Frazer Nash Consultancy (2020) which found:

- The UK has limited experience in the production and manufacturing of rectenna
- Limited available data in regards to experience with operating robotics in orbit

It was also highlighted that although the TRLs are low for these aspects, the report outlined that they still have the potential to be technically feasible by 2050.

Technical Feasibility Primary Research Findings

Main Findings:

- Wireless Power Transmission – the physics are understood and we know it can work, however has not been tested at large enough scale
- Robotics are needed for in-orbit assembly and manufacture – which currently does not exist

Table 1: Technical Feasibility SWOT Analysis

Strengths	Weaknesses
• Wireless power transmission, we know it can work and we understand the physics of it. • WPT can be used for other applications – not just beaming energy. • A new marketplace. • New materials and new types of PV.	• SBSP is a very large structure, will be the largest engineering product ever created. • How novel the system is and trying to advance through technology readiness levels.
Opportunities	**Threats**
• High-concentration photovoltaics which will improve efficiency of the system. • Opportunity for re-usable launch vehicles. • Decreased dependence on fossil fuels. • Digital Twinning – using artificial intelligence to manufacture components.	• Robotics are needed for in-orbit assembly and manufacture of SBSP, however this does not currently exist. • WPT has not been tested at a large enough scale yet. • Millions of antenna being able to work together.

Economic Feasibility Primary Research

Main Findings:

- Large upfront costs – investment is difficult to acquire.
- The energy and space sector merge for the first time – new jobs.

Table 2: Economic Feasibility SWOT Analysis

Strengths	Weaknesses
• Cost of launch per kilogram continues to decrease through the years. • Baseload power that costs lower than equivalent terrestrial renewables. • Cost of development is half of that of a nuclear new-build. • SBSP provides a huge energy market to enable space traffic management and active debris removal.	• Large upfront costs due to the large size of SBSP systems. • The cost of maintaining an SPS. • Unlike most other energy systems, it is difficult to start small. • If there is poor public perception, people are not going to want to fund it.
Opportunities	**Threats**
• The energy sector and space sector have never merged together before – a new industry offering new jobs. • With this new industry will come increased manufacturer capabilities which can be used for applications that isn't SBSP.	• Because of the large cost, initial investment is difficult to acquire. • The levelised cost of electricity.

Importance of eco-design within SBSP

Chanoine (2015) defined eco-design as:

"a preventive approach to mitigate the environmental impacts of a product (good or service) as early as possible in the design phase".

A tool to help with decision making during the eco-design process is Life Cycle Assessment (LCA) - which is standardised by the International Organisation of Standardisation (ISO)

The LCA method allows for significant environmental impacts to be located at any point of the life cycle.

The Space Sustainability Paradox paper by Wilson, et al (2023) reinforces that action is required for space sustainability to aid with issues such as space debris. Thus, it is important for eco-design to become a requirement for SBSP in order to achieve space sustainability.

Life Cycle Approach

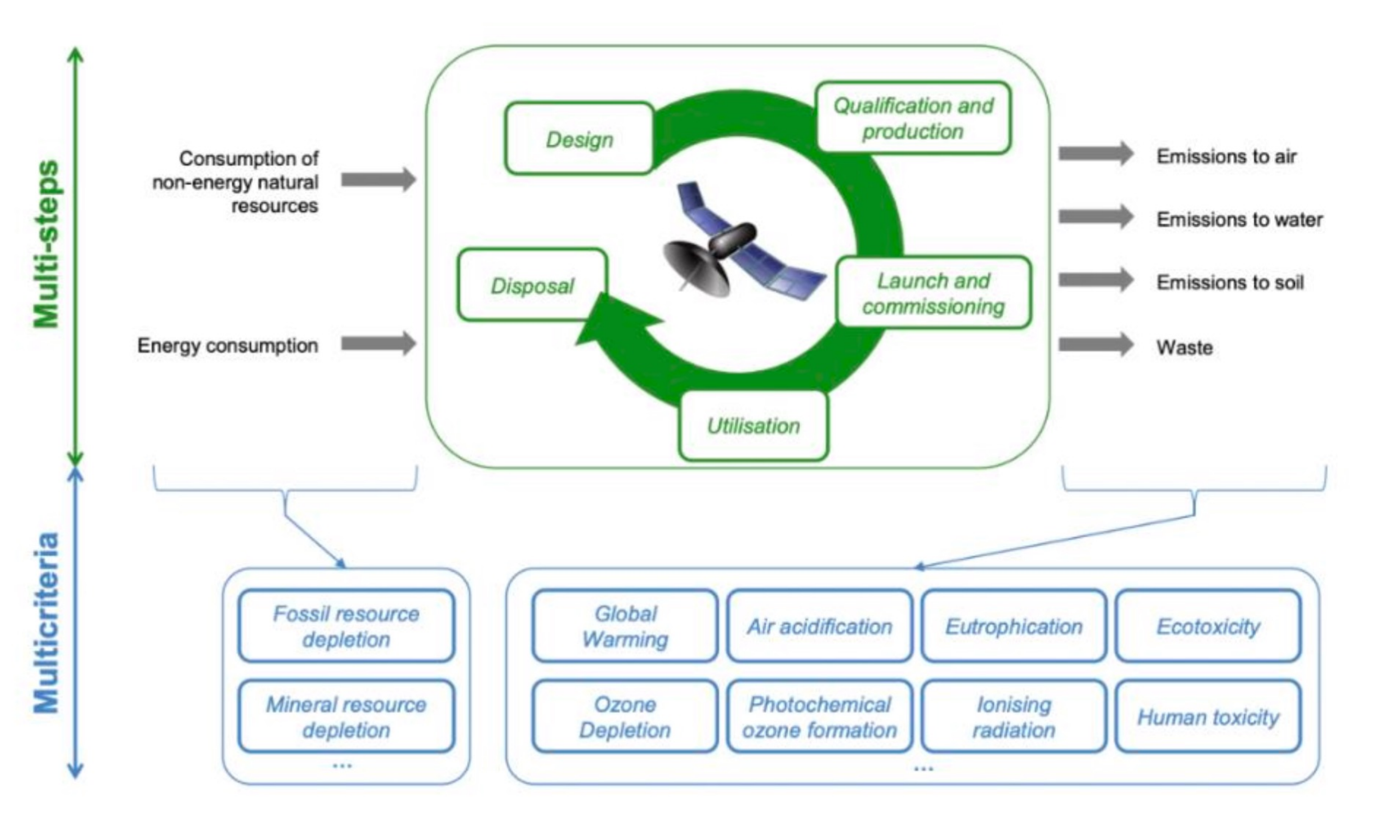


Figure 3: Visual Representation of LCA Approach (Austin, 2015)

Life Cycle Assessment Report

Carried out by METASAT UK and the University of Strathclyde for the Space Energy Initiative – based on the CASSIOPeiA SPS system

Results of the study:

- The study looked at the SEI technology roadmap – in which it was identified that the life cycle carbon footprint of the roadmap is 3.22E+11 kgCO2eq. Results of the study found that the 3.22E+11 kgCO2eq carbon footprint figure has the potential to be lowered with the correct environmental design improvements.
- Radiative forcings of black carbon, aluminium oxide and water vapour from launch were not considered, which could vastly change the results.

Areas where adaptation are required where identified such as:

- The rectenna and the use of aluminium and steel to develop it – along with the rectennas large 76.97km2 structure

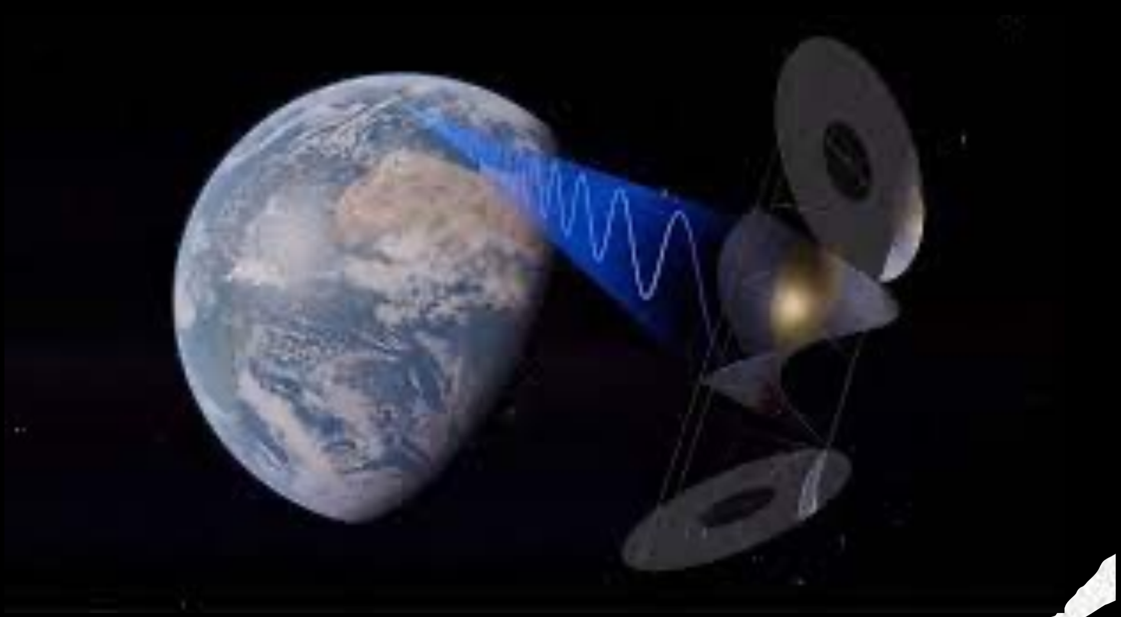


Figure 4: CASSIOPeiA SPS (Cash, 2023)

Eco-Design Primary Research Findings

Main Findings:

- Trying to get companies to see it as an important issue – especially challenging with the lack of sustainability legislation in the space sector.
- Able to quantify and actively reduce your carbon footprint for the first time.

Table 3: Challenges and Opportunities of Eco-design

Challenges of Eco-design	Opportunities of Eco-design
• Trying to get companies to see it as an important issue. • Judgement calls on the most sustainable route and if it is the most likely to help achieve net zero. • Assessments are sometimes based on assumptions – so the unknown is a barrier. • Confidentiality of data.	• For the first time, you are able to quantify and actively reduce your carbon footprint. • Eco-design gives you a transparent design, which can avoid greenwashing. • Reduced environmental impacts trough life. • Company morale – people working on SBSP want to know they're doing the right thing. • Gives you that justification to go out and get funding. • Having a system that lasts longer than immediate profit. • With eco-design you assess really the sustainability of what you are doing so it's assessing whether you can continue doing whatever you are doing in the future. • Marketing and communications.

Conclusions

- SBSP has clear potential in helping the UK to obtain net zero, however only when various challenges are overcome such as the integration of eco-design and development of in-orbit robotics.
- To ensure the sustainable use of outer space, it is crucial for eco-design to become a requirement for SBSP. This would result in eco-design being mandatory for all companies and would also require to be included in strategies and policy papers.

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