ESA Activities towards Space-based Solar Power

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Space Solar Power Symposium, International Space Development Conference

26-27 May 2022

Net Zero by 2050 is a formidable challenge

"The energy sector is the source of around three-quarters of greenhouse gas emissions today and holds the key to averting the worst effects of climate change, perhaps the greatest challenge humankind has faced."

"Achieving net-zero emissions by 2050 will require nothing short of the complete transformation of the global energy system."

"Renewable energy technologies like solar and wind are the key to reducing emissions in the electricity sector, which is today the single largest source of CO2 emissions."

"For solar power, it is equivalent to installing the world's current largest solar park roughly every day."

Net Zero by 2050 is a formidable challenge

"The path to net-zero emissions is narrow: staying on it requires immediate and massive deployment of all available clean and efficient energy technologies."

"Our pathway calls for scaling up solar and wind rapidly this decade, reaching annual additions of 630 gigawatts (GW) of solar photovoltaics (PV) and 390 GW of wind by 2030, four-times the record levels set in 2020. "

"In the net zero pathway, global energy demand in 2050 is around 8% smaller than today, but it serves an economy more than twice as big and a population with 2 billion more people. "

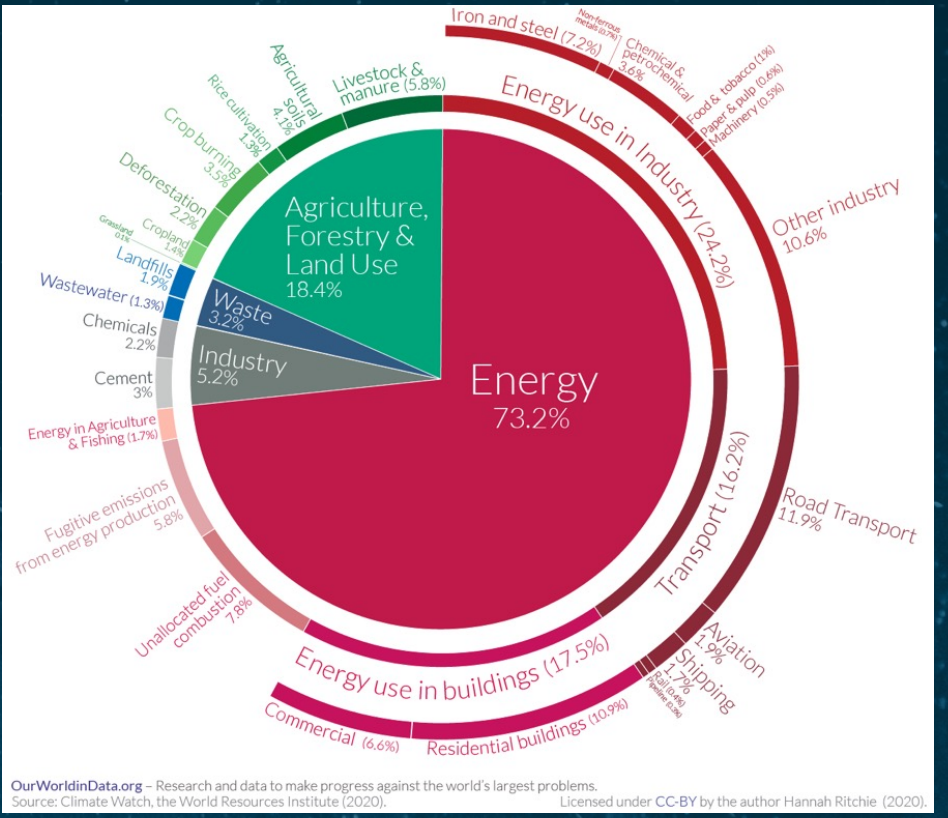
IEA Priority actions recommendations:

Prepare for the next phase of the transition by boosting innovation

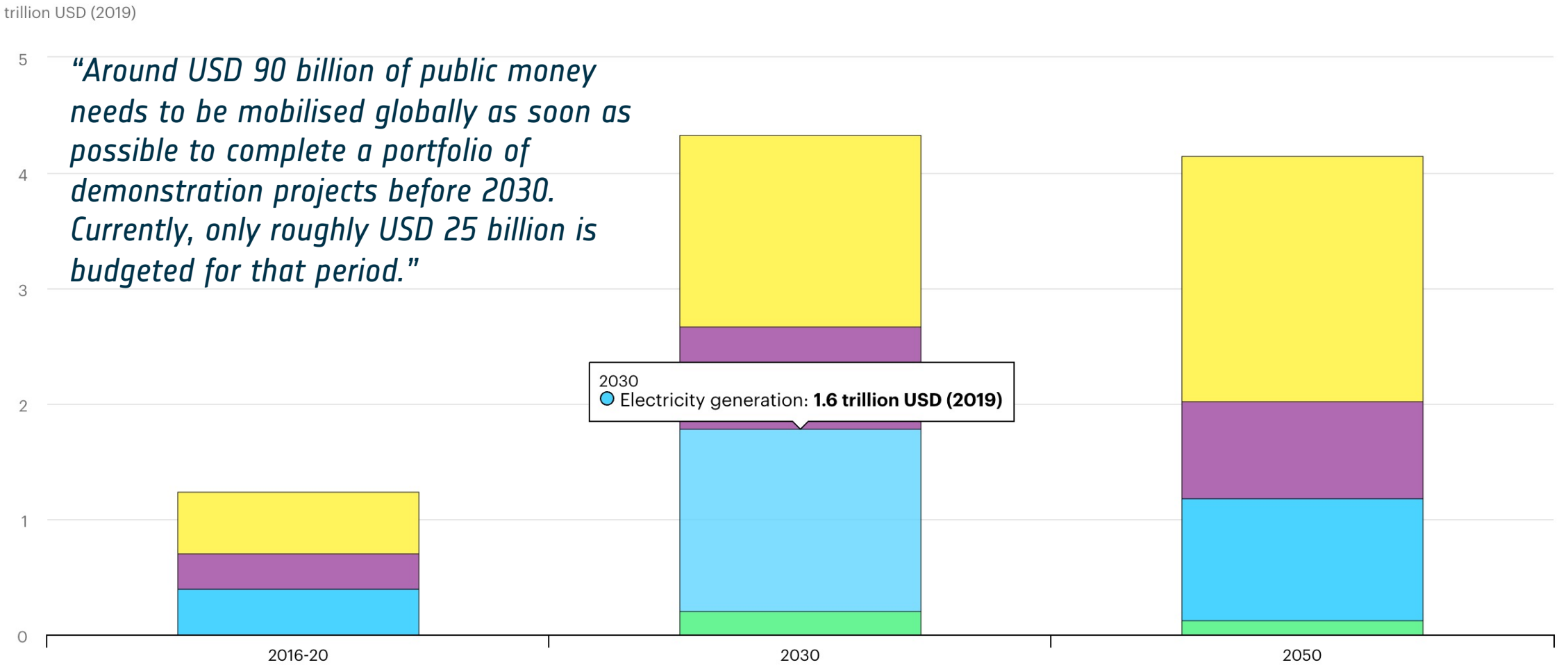
- Clean energy innovation must accelerate rapidly, with governments putting R&D, demonstration and deployment at the core of energy and climate policy.

Address emerging energy security risks now

- Ensuring uninterrupted and reliable supplies of energy and critical energy-related commodities at affordable prices will only rise in importance on the way to net zero.



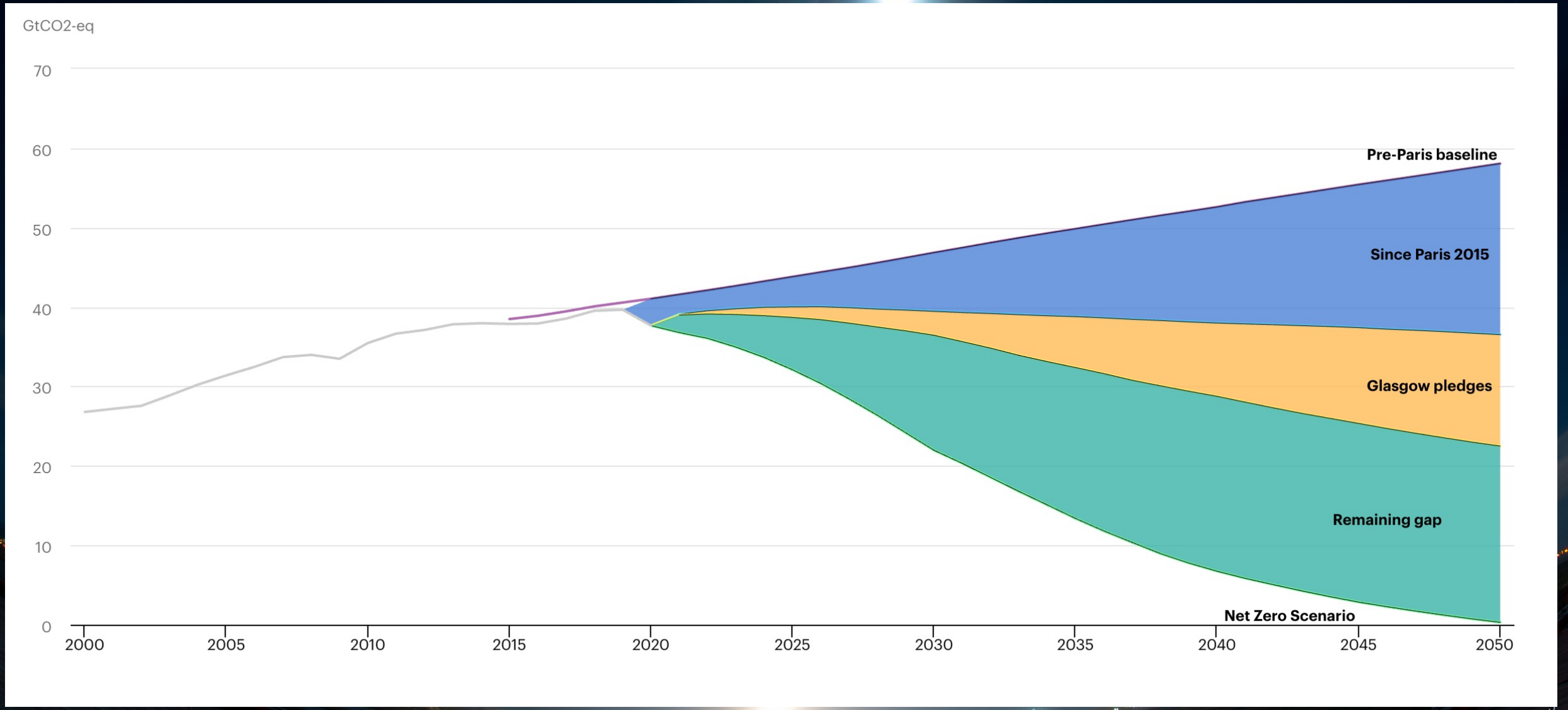
Investments for net zero



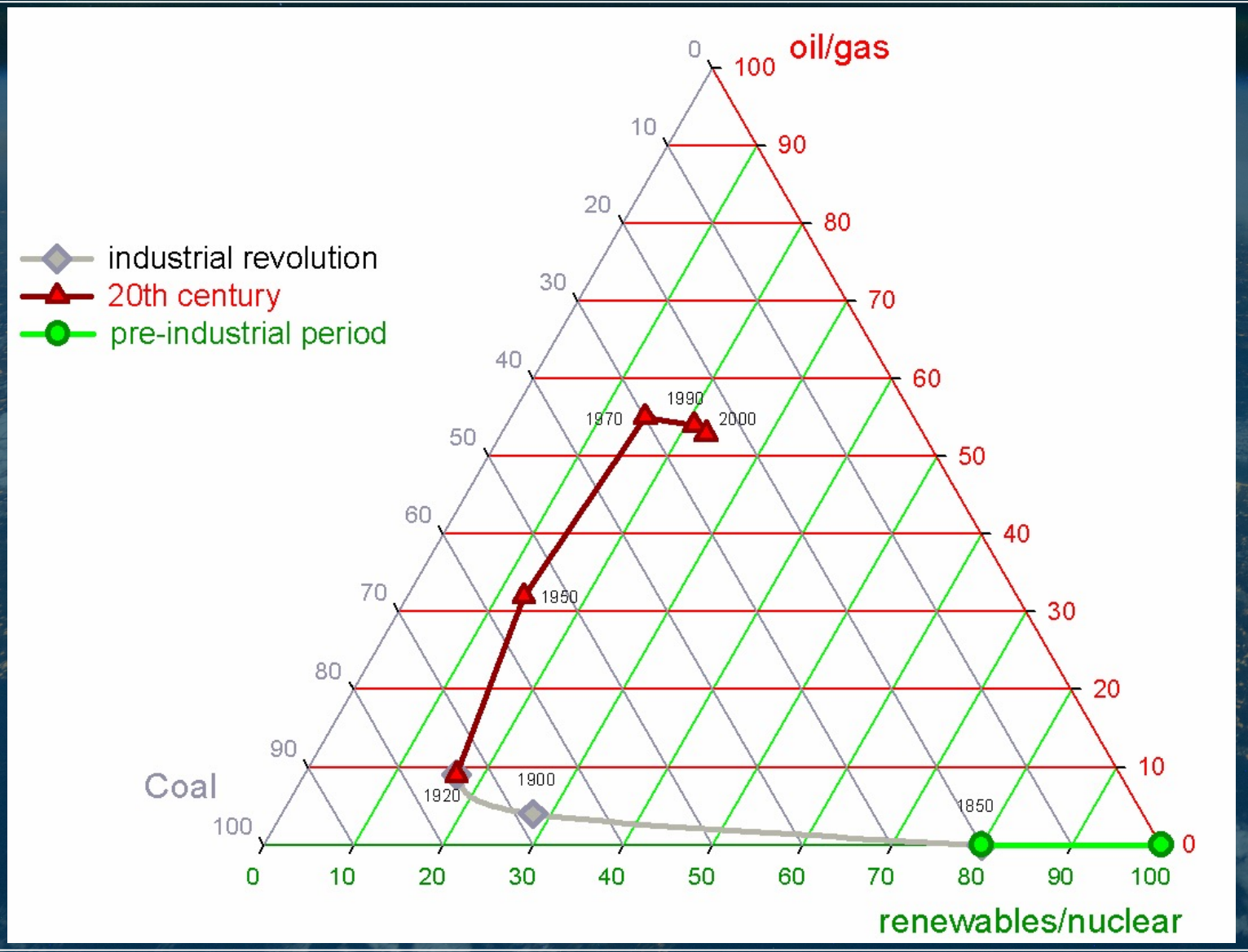
"Around USD 90 billion of public money needs to be mobilised globally as soon as possible to complete a portfolio of demonstration projects before 2030. Currently, only roughly USD 25 billion is budgeted for that period."

IEA (2021), Net Zero by 2050, IEA, Paris
https://www.iea.org/reports/net-zero-by-2050

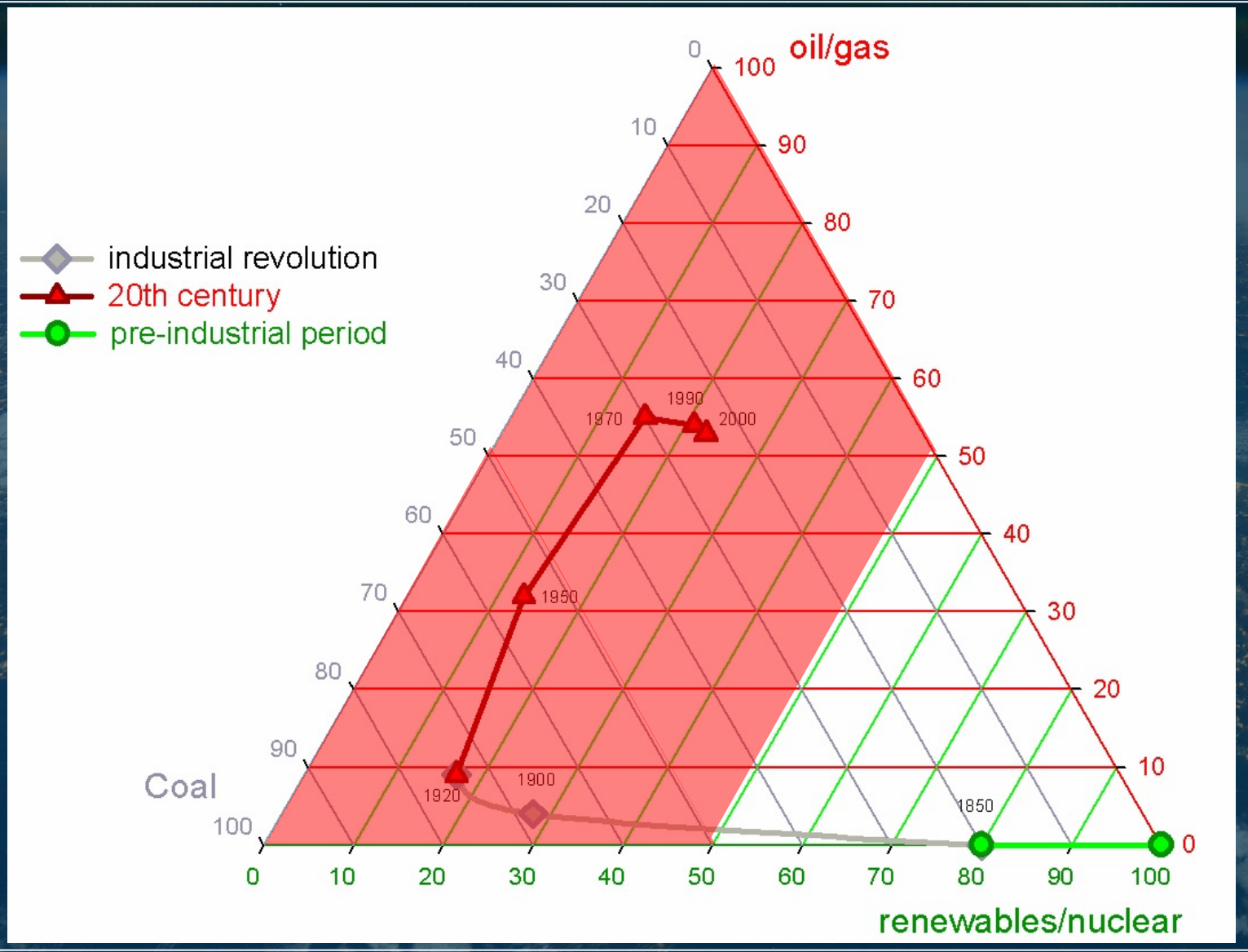
CO_2 - substantial remaining gap



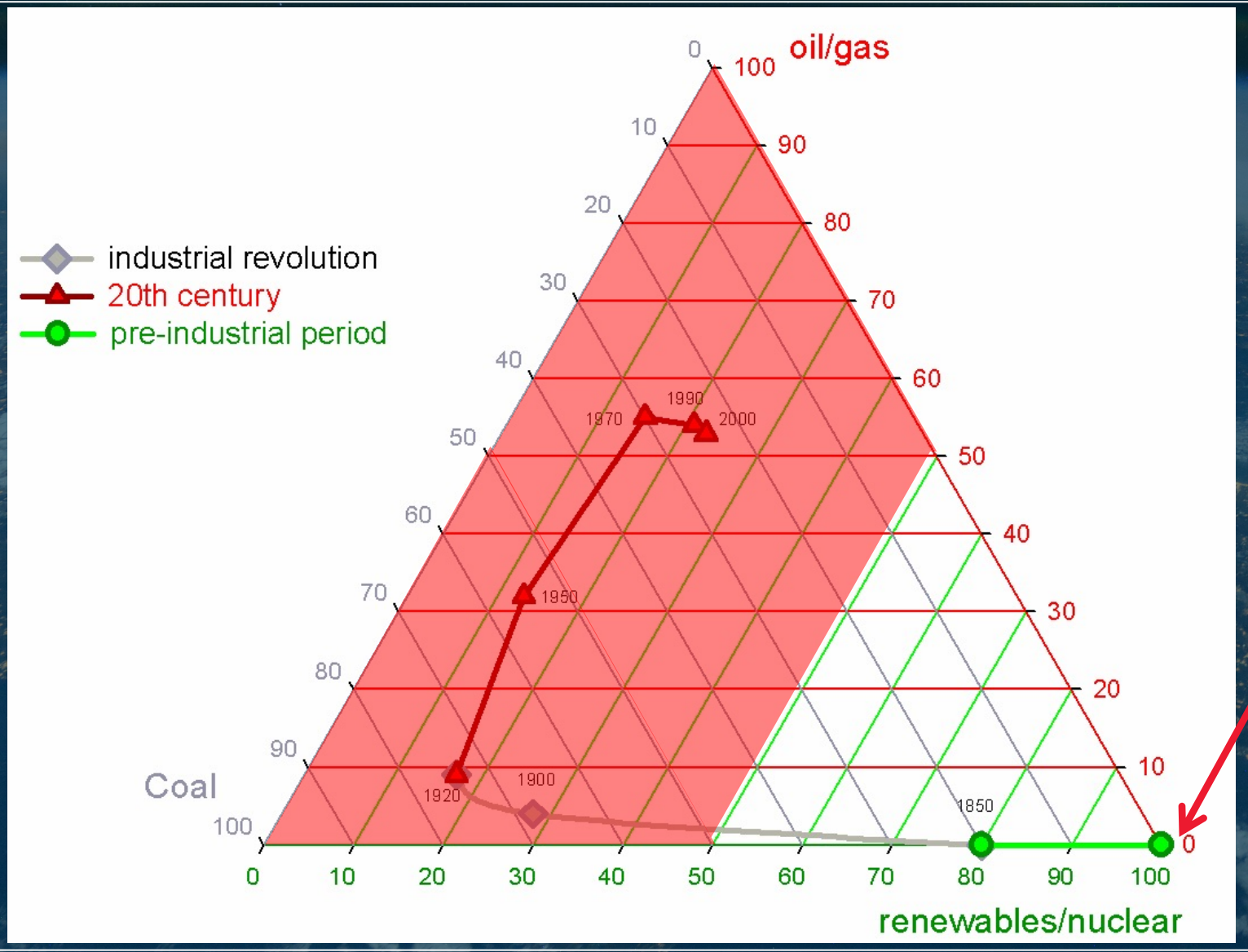
Power sources over time



Power sources over time



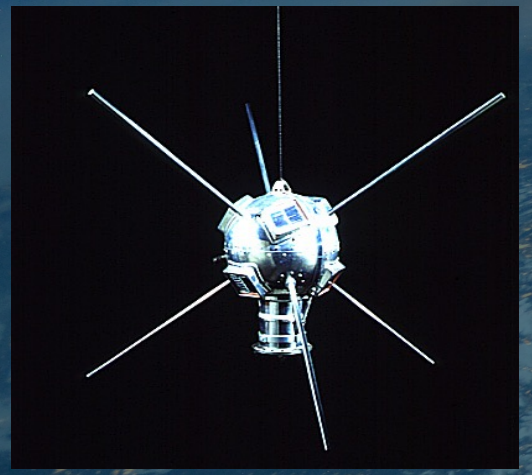
Power sources over time



Spacecraft
=
long-term sustainable target for Earth

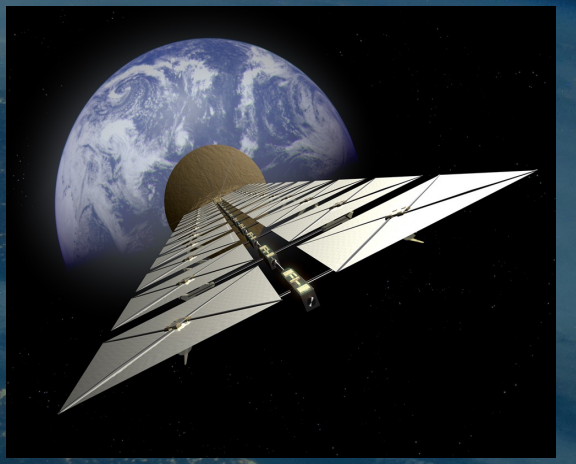
Generation efficiency
Usage efficiency.

From auxiliary power to excess power?



1958
5 mW
Vanguard-I

2010
110 kW
ISS



2040?
>1 GW
SPS

Clean Energy - New Ideas for Solar Power from Space

Idea submission, discussion maturation
October/November 2020
Evaluation closed 3 December 2020

"Energy is central to environmental sustainability. Space missions have to be energy-efficient and require advanced recycling and robotic technologies – especially for exploration – as well as innovative materials sciences. Breakthroughs in all these areas will be pursued and commercialised to support a circular economy and ***climate neutrality in Europe****. Space-based services to* ***support the energy transition****, and potential* ***space-based solar power generation*** *deserve to be further investigated. ESA will strongly support market creation efforts for new applications in these areas."*
J. Aschbacher, Agenda 2025

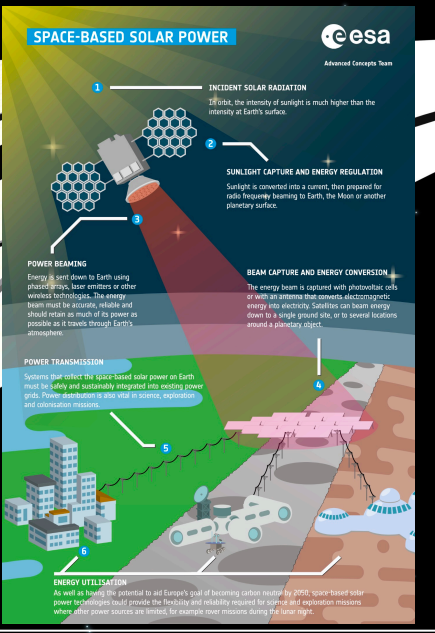
Novel system concepts for Earth, Moon, Mars applications
Novel subsystem concepts or technologies
Novel methods of scaling and integrating space-based solar power into energy grids.
Novel ideas that use in-space construction
New concepts for precursor in-space demonstrations

85 Ideas received

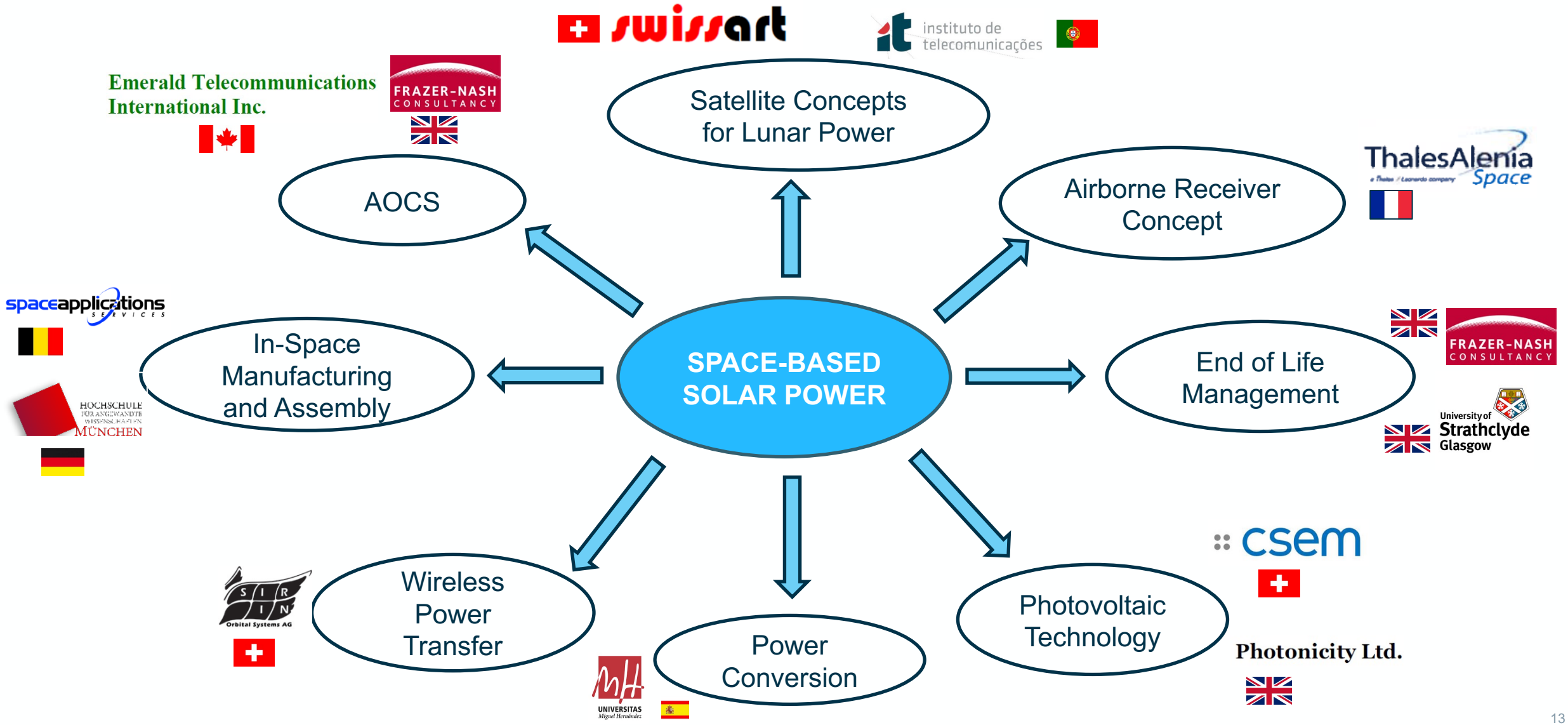
16 Ideas Invited to be Matured into proposal

13 Activities

- 6 studies
- 4 early tech. dev.
- 3 co-funded research



OSIP Campaign on new ideas for Space-Based Solar Power Running Activities



→ THE EUROPEAN SPACE AGENCY

Current options all face **major challenges** to meet Net Zero goals

Scalability **Availability** **Public Acceptance** **Land Use**

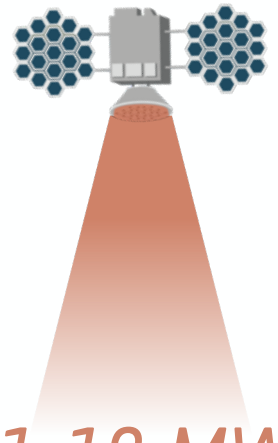
Nuclear Fission projects

Source: The most expensive nuclear energy projects around the world - Future Power Technology | Special Issue | November 2018 (nridigital.com)

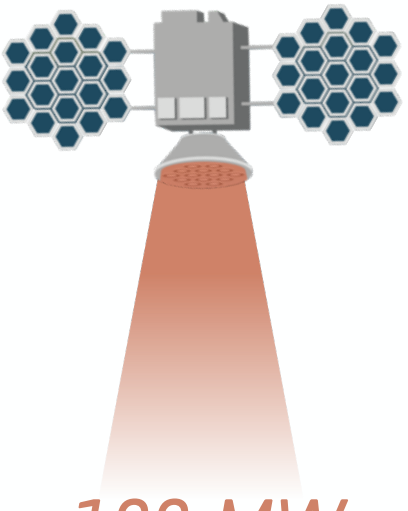
When could commercial SBSP be ready?

Could potentially be accelerated – under study

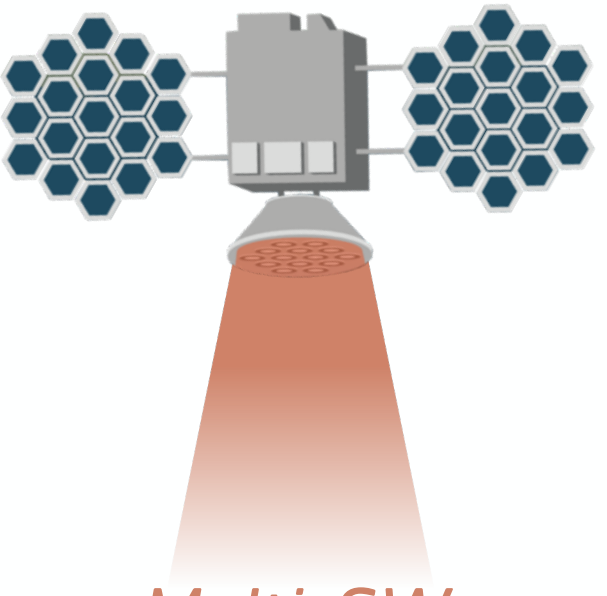
Ground Demos



1-10 MW



100 MW



Multi-GW

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 Analysis Study

Feb 2022 - Aug 2022

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

Parallel contracts led by Frazer-Nash Consultancy (UK) and Roland Berger (DE)

ESA Cost-benefit Analysis Study – Preliminary findings (NFC)

Technical feasibility

- GW-scale power station is very challenging but feasible to be developed by 2040

Economic feasibility

- SBSP can displace fossil sources and could be cost-competitive with renewables when considering storage costs.

Potential market:

- Theoretical demand for between 40 and 50, and potentially up to 200 SPSs by 2050 based on economic analysis.

ESA Cost-benefit Analysis Study – Preliminary findings (NFC)

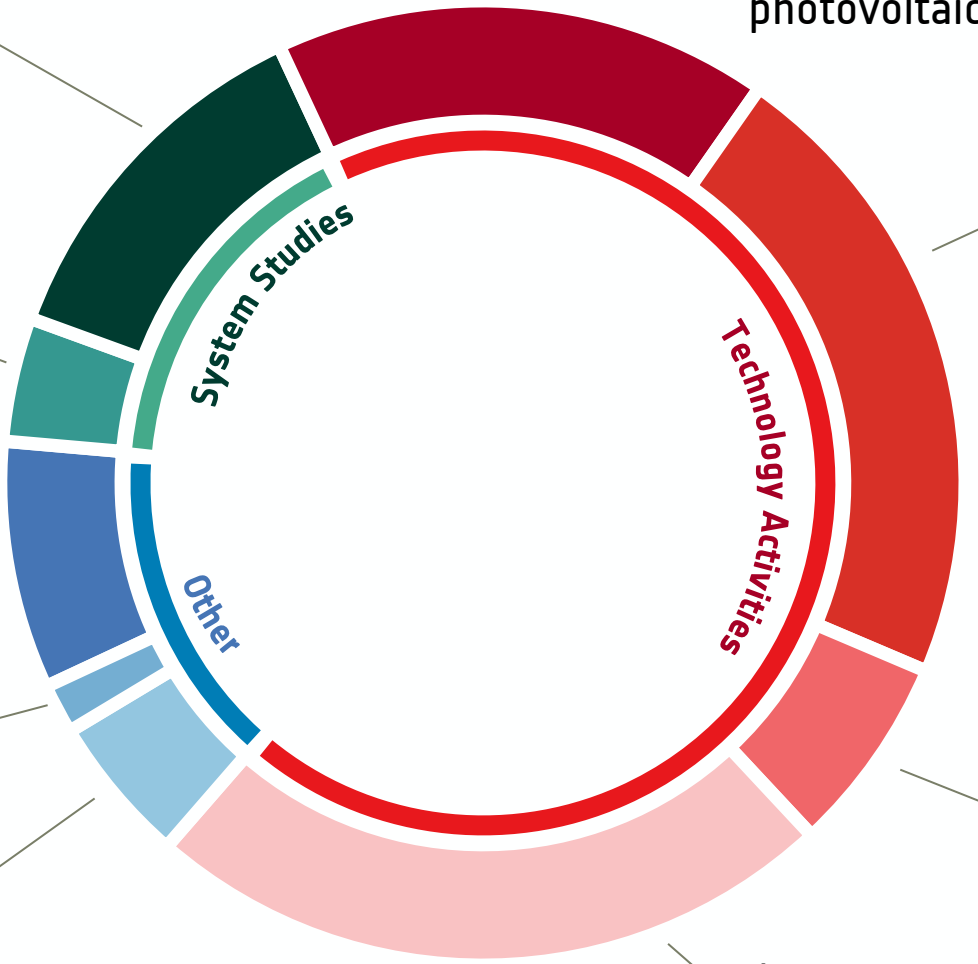
Preliminary findings on Benefits of SBSP	
Economic	• Increase and diversification of supply to meet clean energy demands • Price stability and cost savings • Market integration – providing stability to the grid • Spill overs from R&D and scale-up of industrial capacity associated with SBSP development
Environmental	• Avoided emissions & accelerated transition to Net Zero • Reduced pollutants • Nature protection and biodiversity • Reduced dependence on Carbon Capture and Storage
Strategic	• Energy security • European independence in energy generation • Strategic tool to support partners • First-mover advantage
Health	• Avoided allocation of land • Health co-benefits

Proposed Preparatory Programmatic Steps 2023-2025

- A commercial GW scale space based solar power plant operational in 2040, in time to upscale to make substantial contributions to NetZero 2050, requires pilot plants in the 1-100MW range in the early 2030, requiring a programmatic decision by 2025.
- While substantial progress has been made in many key areas such as space hardware cost and maturity, key technology domains, and launch costs, a decision in 2025 for such an in orbit demonstration mission requires maturing technologies and preparing a system baseline, addressing main uncertainties and challenges:
    - Focus on technology development, research and demonstration activities
    - System studies for solid baseline

System Studies for GW-scale Solar Power Satellites (Phase 0)
System studies for flight demonstrator mission
Ground/aerial demonstrators of power beaming and reception
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
Environmental, health & safety studies & testing

Proposed Preparatory Focus Steps



Prep. Studies for SPS Demonstrator (Phases 0/A/B1)

Prep. Studies for GW-Scale SPS (Phase 0)

Ground / Aerial Power Beaming Demonstration

Stakeholder Engagement and Outreach

Environmental, Health & Safety Studies

Highly mass-efficient photovoltaic systems

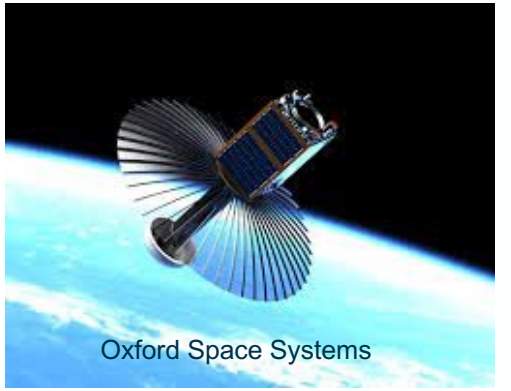
Highly efficient RF generation and beam forming

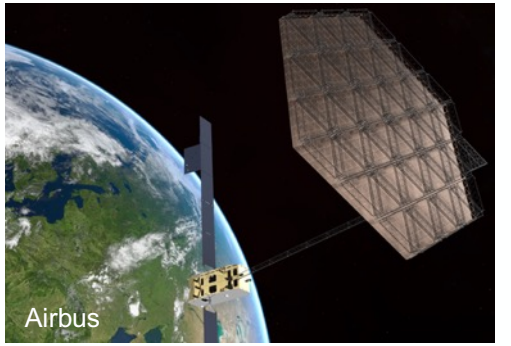
High power management and distribution

Large structure deployment, in-space manufacturing, robotic assembly

Synergies 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





Proposed Preparatory Key Research Areas 2023-2025

Human Health

Assessing risks to human life health

Ionosphere & Atmosphere

Understanding beam interactions with ionosphere and impacts on atmosphere / weather

Key Research Areas

Environment

Assessing risks to flora and fauna in rectenna vicinity

Launch / Deployment

Understanding environmental impact and embodied carbon of deployment

Technology & Infrastructure

Understanding potential impact of beam interference on aviation, and ground infrastructure

CONCLUSION

- Substantial progress in key areas such as space hardware cost and maturity, key technology domains, and launch costs
- Increasing urgency to address energy sector challenges (environmental, supply security)
- Ongoing cost-benefit analysis studies revisiting European analysis last made in 2005.
- Space-Based Solar Power appears to be feasible to provide substantial clean and secure energy supply for achieving European net zero.
- Many uncertainties and challenges still exist, which need to be addressed.
- Preparatory programme for an informed programmatic decisions in 2025.