Towards Defining the Circular Space Economy

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INTRODUCTION

- Space faces significant sustainability issues: Orbital congestion, debris accumulation, increasing launch activity.
- 73 % of tracked Earth-orbit objects are debris; ~1.2 million untracked 1 – 10 cm objects pose major threat [1].
- Mitigation by deorbiting spacecraft or relocation to graveyard orbits follows a linear "make–take–waste" model, which is economically inefficient and environmentally unsustainable.
- Applying circular economy (CE) principles promises long-term sustainability, cost reduction, and higher resource yields [2].
- Yet the circular space economy (CSE) remains undefined, with unclear scope and inconsistent terminology [3-11].

OBJECTIVE

- Provide a structured CSE definition to enable shared understanding across stakeholders.

METHODOLOGY

- Analysis of CE/CSE definitions and of Earth/space as operational environments inform the CSE definition (Fig. 1).

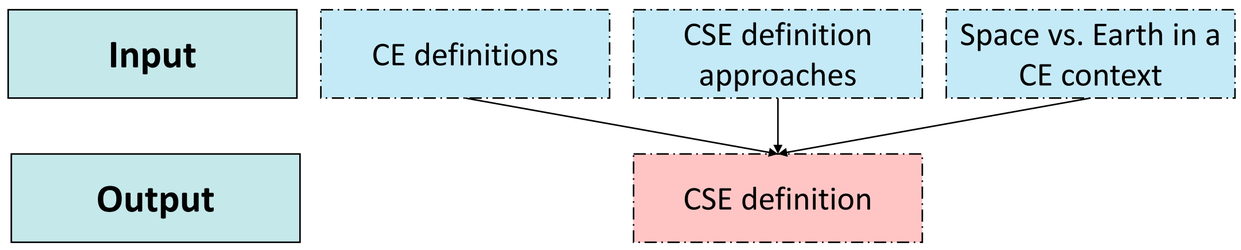

Fig. 1: Methodological flowchart.

RESULTS

- Structural analysis of CE definitions resulted in a coding framework applied to CSE definition approaches (Table 1).
- Comparison of Earth and space as distinct operational environments (Fig. 2) informed the following CSE definition:

Table 1: Coding framework (partly adapted from [2]) applied to nine CSE definition approaches, sorted by year of publication.

Source	Core concept	Aims	Enablers	Beneficiaries	Framework / Conceptual model
[3] Wilson and Vasile (2023)	X	X	X	–	X/–
[4] Leonard and Williams (2023)	X	X	X	–	–
[5] European Space Agency (2023)	X	X	–	–	–
[6] Jah (2024)	X	X	X	–	–
[7] Bahlmann et al. (2024)	X	X	X	–	–
[8] Turner et al. (2024)	X	X	X	X	–
[9] Dailey et al. (2024)	X	X	–	–	–
[10] NOAA Office of Space Commerce (2025)	X	X	–	–	–
[11] Bennett (2025)	X	X	X	–	–

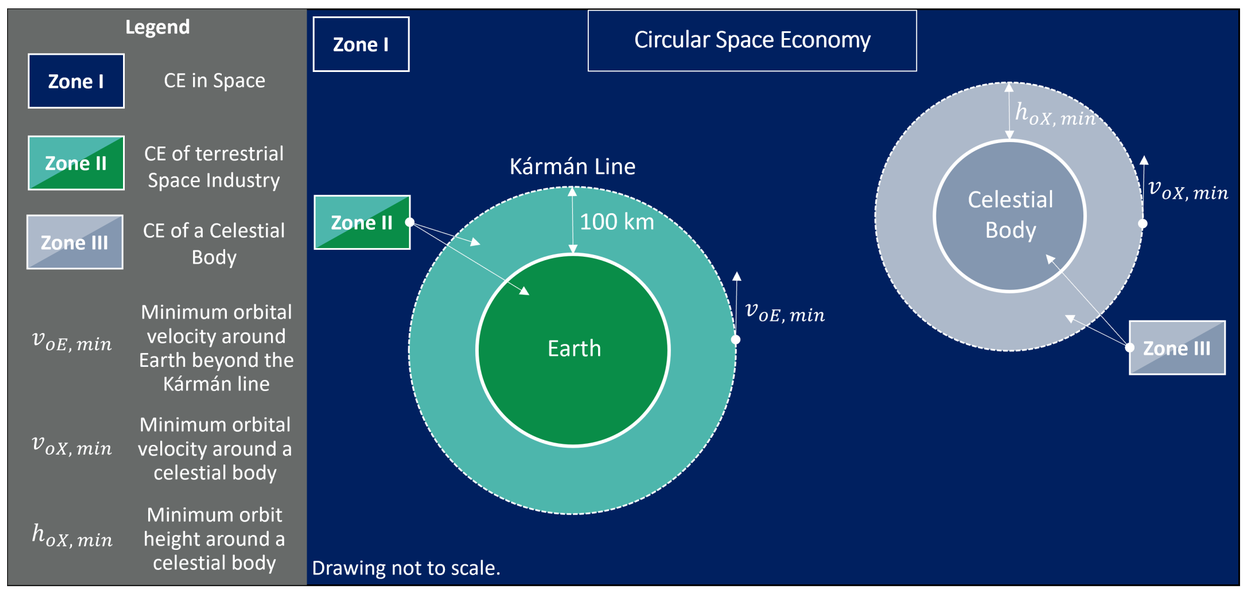

Fig. 2: The three operational environments and terminology of the CSE.

Core concept, beneficiaries: The circular space economy (CSE) is an economic system that operationalizes sustainable development in space for the benefit of businesses, society, and the environment. It consists of three operational domains: (I) The circular economy in space, (II) the circular economy of the terrestrial space industry, and (III) the circular economy of celestial bodies. An object is considered part of the circular economy in space once it reaches orbital velocity around a celestial body; for Earth, this implies sustained presence beyond the Kármán Line, which marks the regulatory boundary to space.

Aims, beneficiaries: The CSE aims to become independent from terrestrial feedstock, and linear practices such as the consumption of finite resources, spacecraft deorbiting, and the generation of space debris. Further, the CSE aims to contribute to long-term space sustainability as defined by the United Nations, enabling current and future generations to access and expand the peaceful use of space, while reducing the environmental impact of the space industry both in space and on Earth.

Enablers: The CSE is enabled by design, international cooperation, policy, technological innovations, and financial incentives, bridging the gap to viable business models.

Conceptual Model / Framework: Applicable to technological and biological resources, the CSE is conceptually grounded in the 10R framework: Rethink, reduce, resell/reuse, repair, refurbish, remanufacture, repurpose, recycle, recover energy, and re-mine.

CONCLUSION

- First structured CSE definition offers a framework to discuss sustainability issues in space and on Earth.
- A shared understanding is essential to streamline efforts across stakeholders.

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