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EDITORIAL

The Largest Emission Sector Direly Needs More Research Funds to Clean-Up

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"Biomass growing and harvesting; mineral and fossil resource extraction; and processing of materials, fuels and food accounted for more than 55% of global greenhouse gas emissions in 2022 and more than 60% if land-use change impacts are considered" reports the international resource panel in their 2024 global resource outlook (United Nations Environmental Program 2024). In a nutshell, material sourcing and processing for all walks of life contributed 55% of the global emission. An inadvertent surge in material usage by 60% than the 2022 levels is predicted (United Nations Environmental Program 2024); if the current habits of sourcing and processing prevail, the future of a liveable planet Earth is uncertain. The report also notes that "the scientific community has never been more aligned before or more resolute on the need for urgent global transformation towards the sustainable use of resources" (United Nations Environmental Program 2024); however, practical changes are yet to be seen. Obviously, switching into a circular economy and circular use of materials are unanimously opined as the way forward for a sustainable planet. Circular economy, by definition, is an intentionally designed economic system wherein life means are made cyclic, similar to natural life cycle, such that resources are not wasted or accumulated in air, soil, or water but avoid adverse health effects on humans as well as other living beings (An Introduction to Circular Economy 2021). Circular materials, on the other hand, are "renewable materials" or "sustainable materials" or "low-carbon materials" that foster a healthy living environment and a circular economy via the elimination or reduction of associated greenhouse gas emissions and resource depletion and wastage (Ramakrishna and Jose 2022). Circular materials are purposely designed with lower environmental footprint and social costs and higher circularity potential while satisfying the cost as well as functional requirements. The primary purpose of the Springer Nature journal *Materials Circular Economy* is to promote and direct circular materials research for sustainability.

The circular materials research is steadily progressing during the last decade (Fig. 1a); however, the statistics of growth do not correspond to a situation requiring to eliminate 55% of the total global green house gas emission. In contrast, the research is much more intensive in a domain aimed for an energy transition from dirty fossil fuels to clean electricity in a relatively lower emission sector than materials sourcing and processing, i.e., electrification of the products and services (Fig. 1a). The primary objective of the research on energy storage devices is to develop materials and systems to increase the storing capability, faster rates of storage and delivery, and longer use. While not forgetting the fact that longer use will reduce the environmental load over time, the factors that also need to be considered for a typical energy storage device are (i) ~ 20 tonne of CO_2 emitted per processing of one tonne of lithium; (ii) require 1.9 million liters of water and > 150 GJ energy to process one tonne of lithium; and (iii) average carbon emissions from electrode materials processing is 89 kg CO_2-eq/kWh. However, the investment is primarily on to develop a more efficient battery but not to lower the resources footprints of the battery materials.

Research and development (R&D) are cost intensive. The nations or the institutions investing significantly to R&D become leaders of advanced technologies and stronger economies. Statista.com reports that global spending on R&D

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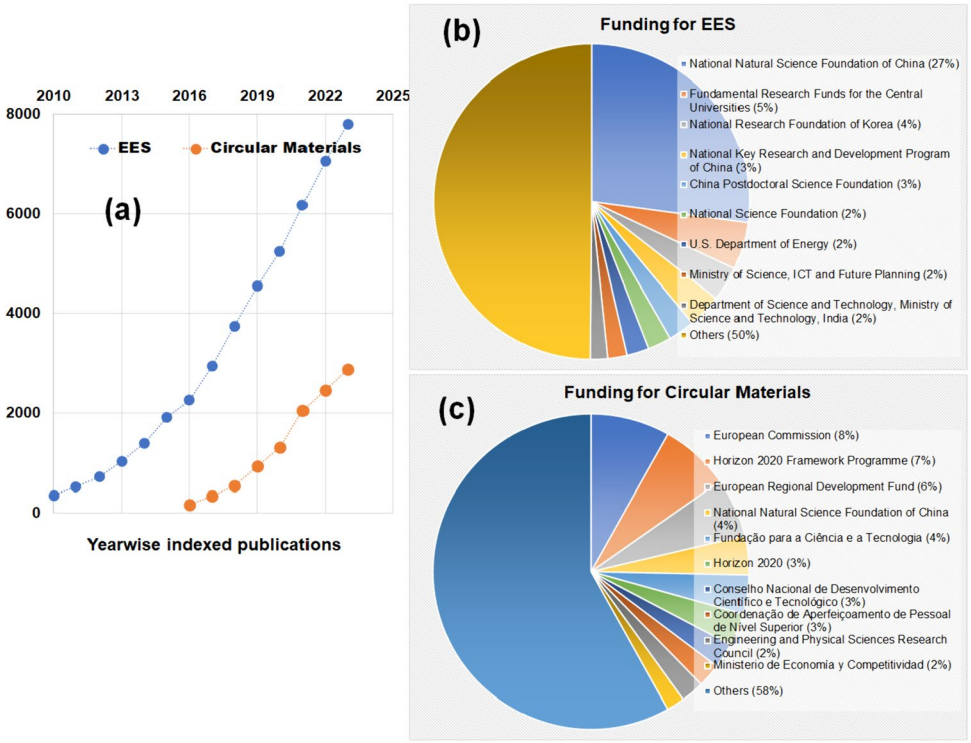

Fig. 1 Statistics of (**a**) research publications and organizations funding (**b**) electrochemical energy storage research and (**c**) circular materials. The entry "others" are constituted by 149 out of 159 institutions/organizations supported the research publications in (**a**). The infographics has been developed from the data derived from the Scopus database on 06 March 2024 using the keywords *electrochemical energy storage* (for EES) and *"circular economy" AND materials* (for circular materials). The quantum of funding is unknown; the fraction is based on the number of publications acknowledging the organizations

has reached a record high of ~ US$ 2.5 trillion in 2022, 80% of which is from about 10 countries. As part of the Sustainable Development Goals (SDGs), countries have pledged to substantially increase public and private R&D spending as well as the number of researchers by 2030. Once again, we invite your attention to a funding scenario comparison between "circular materials" research and "energy storage" research. Figure 1b, c lists the organizations funding these researches; obviously, the giants boasting research supremacy fund more to batteries than developing circular materials. Apparently, large funding for energy storage is reflected in larger number of publications as well. These investments in electrical energy storage are now paying off; millions of kilometers are run today on batteries. But the materials that make batteries are still not green but contribute intensively to environmental load by the time they serve as an energy storage medium. The organization funding energy storage has clearly been established as engines of change, and we appeal to fund for a more devastating domain contributing to environmental adversity (i.e., materials sourcing and processing). Those who are already funding to develop circular materials, a sustained world will thankfully acknowledge the pioneers.

Tailpiece: Spending on military supersedes that on R&D for most countries. Do we prefer geopolitical conflict and war over a sustainable planet?

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