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Editorial: Circular carbon systems and processes

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Editorial on the Research Topic
Circular carbon systems and processes

The concept of circular economy comes primarily from the area of material resources. Mostly involuntarily it is brought into a close relationship with waste management, as it should (also) address other steps in the life cycle of products and components (Bourguignon, 2016). The focus on carbon (or specifically CO_2) arises in the area of avoiding climate change through emission reduction, implemented through a transition to sustainable energy systems (Mathiesen et al., 2011; Böhm et al., 2021). Both concepts, the circular economy and sustainable energy systems, are unavoidable parts of a sustainable economic system that has already been started to be implemented and will ideally achieve realization in the mid-term future.

However, the two concepts are developing almost separately and in parallel. Carbon is addressed in both of these concepts, and thus, Circular Carbon shall analyze their intersections, investigate the overlaps and contradictions, and provide a joint field of action to coordinate them.

In the light of the Paris Climate Agreement and the subsequent policy packages such as the European Union's Green Deal (European Commission, 2019), the relevance of Circular Carbon becomes evident. We use the term Circular Carbon to describe a merging of the concept of circular economy and the general effort to reduce carbon (dioxide) emissions. The reduction of carbon emissions should therefore be achieved through circular technologies and processes.

However, no uniform definition has yet been found for the term circular carbon. In the Task "Circular Carbon" of the IEA Technology Collaboration Platform in the area of Industrial Energy-Related Technologies and Systems (IETS, see iea-industry.org), the involved experts' understanding of the term has been discussed. Some understand circular carbon to be a very tight construct that takes carbon into a permanent technical circular system and doesn't release it again. Others also understand the carbon cycle to include the use of fossil fuels with carbon capture and permanent storage (CCS). Again, others see the achievement of the minimum requirement of circularity when any reduction in emissions is achieved, for example by replacing a fuel with e-fuels (implying that new CO_2-emissions are avoided but the before-captured CO_2 is released to the atmosphere). At the same time, the bioeconomy also works as a cycle and interacts in a variety of points, for example, among other aspects, in carbon application, as a carbon storage, and for the use in bioenergy carbon capture and storage (BECCS) (Moser et al., 2022). None of the experts' perception is wrong *per se*, reflecting the breadth of this field, opening it for the much-needed research and development.

The progressive decarbonization of industries, the energy system and the whole economy requires the research and development of advanced technologies for the safe and efficient use of carbon and carbon-based products. To enable policy and market acceptance of circular carbon approaches, the evaluation of these pathways is inevitable.

We are happy that our Frontiers Research Topic "Circular Carbon Systems and Processes" has attracted relevant contributions from the field. The six associated publications cover many of the sub-areas outlined above.

Looking at the above explanations is a good bridge to the first published article. Tan and Lamers take out the field of circular bioeconomy concepts in their perspective paper and give a deeper insight into its interaction and integration in the circular economy concept. They argue that the circular bioeconomy creates an additional carbon sink capability in the technosphere by utilizing biogenic carbon. In their research article, located in the same sub-field, Rodin et al. perform a life cycle assessment of a novel electrocatalytic process for the production of bulk chemical ethylene oxide. They investigate a carbon capture and utilization process chain based on biogenic carbon, which—in line with the above-mentioned integration of the concepts—considers the utilization of renewable electricity.

In their policy and practice review, Henrion et al. analyze the specific area of the construction sector, which can contribute to infrastructure renewal with significantly reduced CO_2 emissions through political measures at different government levels. In their research article, Carbone et al. specifically address carbon capture in the cement industry by "evaluating the carbon footprint of cement plants integrated with the calcium looping CO_2 capture process", whereby they compare the tail-end and the integrated approach. As Cannone et al. describe in their research article, innovative calcium looping processes can also be used as high-density, high-temperature seasonal energy storage systems.

Aside of technological development and ecological viability, economic feasibility is crucial for a technology's roll-out and market penetration. In their research article, Böhm et al. investigate the techno-economic performance of thermally integrated co-electrolysis and methanation for achieving closed carbon cycles at the level of the industry itself. They conclude that power-to-gas systems as part of carbon capture and utilization (CCU) applications represent a valuable option for hard-to-abate sectors.

We thank the authors and reviewers for their contributions and cooperation. We are pleased to be able to continue the exciting topic and hereby refer to the Frontiers Research Topic "Circular Carbon Systems and Processes: Volume 2".

Author contributions

Conceptualization: SM. Writing-original draft: SM, SS, and AL. All authors contributed to the article and approved the submitted version.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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