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Editorial: Emerging Technologies and Associated Scientific Advancements for CCUS Deployment

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Editorial on the Research Topic

Emerging Technologies and Associated Scientific Advancements for CCUS Deployment

The urgency in meeting ambitious targets for removing carbon from our emissions and air calls for rapid scientific and technological advancements across several scales – ranging from developing molecular-scale insights into the reactivity of CO_2, to advancing thermodynamically favored reaction pathways for carbon removal, and evaluating the scalability of technologies for CO_2 capture, utilization, storage, and removal. In this context, our special issue titled, *Emerging Technologies and Associated Scientific Advancements for CCUS deployment*, features a unique compilation of studies that discuss pathways, strategies, and technologies for closing the carbon cycle and removing carbon from our emissions and air that are timely and necessary.

Decarbonizing our energy supply and defossilizing our chemical processes are essential for meeting our energy and resource needs in a sustainable manner. Approaches to activate CO_2 for conversion to fuels, chemicals, and materials using chemical and electrochemical pathways are being actively investigated with the aim of closing the carbon cycle. One of the less explored approaches to activate CO_2 involves the use of nuclear irradiation. One of the key advantages of harnessing nuclear energy is the lack of intermittency in operation compared to solar and wind energy resources, and the ability to utilize different forms of radiation to activate CO_2. In this context, Ramirez-Corredores et al. describe pathways for chemically upgrading anthropogenic CO_2 to basic chemicals and fuels using nuclear irradiation. The ability to directly use energy resources to transform matter to meet our chemical needs is unique to nuclear energy resources. α, β, and γ radiation emerging from nuclear resources can be uniquely harnessed to produce the next generation of chemicals by activating CO_2. Advancements in small modular nuclear reactors will allow us to realize these pathways for producing the next generation of fuels and chemicals using anthropogenic CO_2, thus allowing us to close the carbon cycle while meeting our energy needs. This approach is a less explored but highly transformative pathway to explore CO_2 activation.

Articles in this special issue discuss pathways to remove CO_2 from our emissions, such as carbon mineralization, that are complimentary to and compatible with the advancement of CO_2 capture, utilization, and storage technologies. Carbon mineralization involves converting CO_2 to inorganic calcium or magnesium carbonates, and it can be harnessed and accelerated to produce re-useable carbonate-cemented products, as reviewed by Hills et al.. To successfully implement carbon mineralization technologies at scale, the development and application of integrated frameworks and decision support tools is essential, as decribed by Bourgeois et al.

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A perspective on the state of novel CO_2 utilization technologies is provided by Warsi et al. Parallels that can be drawn from the development of two successfully developed hardware-heavy technologies, the solar and the automobile industries, to advance CO_2 utilization technologies are discussed. Drawing on historical case studies from other markets and start-ups, including Bergen Carbon Solutions as described by Sareen and Sagmo, is crucial for the commercialization of CO_2 utilization technologies that have the potential to constitute a multi-billion dollar commodity market. This unique collection of articles is intended to raise awareness associated with decarbonizing our energy supply and defossilizing our chemical processes for a sustainable energy and resource future.

AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication.

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