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Editorial: Rising stars in carbon capture, utilization and storage: 2022

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Editorial on the Research Topic
Rising stars in carbon capture, utilization and storage: 2022

Combating global climate change will require decades of scientific and engineering innovation and discovery in the field of carbon capture, utilization, and storage. Researchers in this community have laid a strong foundation of established CCUS concepts, chemistry, engineering, and fundamentals, which have enabled the first technologies to be deployed. This decades-long transition to a net-zero and ultimately negative emissions future will continue for generations. Thus, we must identify the future leaders, as it will be their discoveries, innovations, and leadership that will launch the next-generation technologies needed to further this critical transition. In this Research Topic, we showcase five up-and-coming experts in CCUS in the early stages of their careers and their innovative research in the areas of CO_2 capture, modeling, and catalytic conversion.

The first article (Ah-Hyung Park et al., 2013) introduces marine carbon dioxide removal (MCDR), an emerging approach to enhance large, commercialized carbon storage that includes the Earth (i.e., ocean) within its system boundary, considering the fact that oceans constitute the largest natural sink of CO_2. The authors show that alkalinity enhancement and biologically inspired CO_2 hydration reactions can shift the equilibrium of ocean water to pump more carbon into this natural sink. This technology is described in terms of ocean carbon capture, as also discussed by Digdaya et al. (2020), in which CO_2 captured by the ocean is harvested and converted into chemicals, fuels, and materials using renewable energy such as offshore wind. This paper which summarizes these emerging and innovative technologies, demonstrates that organic and inorganic carbon from ocean-based solutions can replace fossil-derived carbon and create a new carbon economy. The authors address how to develop these ocean-based CCUS technologies without unintended environmental or ecological consequences, which will create a new engineered carbon cycle that is in harmony with the Earth's system.

In an alternative approach, the relationship between electricity–gas integrated energy systems and carbon capture technologies is tackled by Yang et al. In this study, a liquid storage carbon capture power plant (LSCCPP) with solution storage was created by analyzing the "energy time-shift" features of the solution storage, and a joint operating model of the LSCCPP and power-to-gas (P2G) was developed. That is, this paper demonstrates a low-carbon economic dispatch model for an integrated electricity–gas energy system with the LSCCPP, with the goal of achieving the lowest overall system cost. Additionally, the authors further solved the proposed dispatch model by transforming

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the model into a mixed-integer linear programming problem and using CPLEX. In summary, this work shows that the suggested low-carbon dispatch model is a significant reference for enhancing the system's use of wind power and accomplishing the low-carbon efficient functioning of the integrated electricity–gas energy system.

Effective analysis methods are being devised to predict the cost projection of natural gas combined cycles (NGCC) with post-combustion carbon capture (PCC). A new method based on post-combustion carbon capture to predict costs in combined cycle power plants has been proposed by Diaz-Herrera et al. In this study, a thermo-economic analysis was performed considering the second law efficiency for the CO_2 separation process and the CO_2 avoided cost (CAC) as the main indicators. It should be emphasized that several critical variables influencing the overall cost of the plant were considered in this study, such as the work required for solvent regeneration, technology maturity, learning rate, carbon tax credit, and carbon capture level. According to the authors' analysis, this paper demonstrates that Nth-of-a-kind plants could potentially decrease the levelized cost of electricity by 10%–11% and the CAC by 21%–23% compared with first-of-a-kind plants. It is also concluded that the CAC for Nth-of-a-kind plants is expected to be, in the best scenario, as low as $69/t CO_2. Thus, this paper gives us a clear direction toward post-carbon capture technologies that, if applied in these plants, might need an at least similar carbon tax value to ensure their operation during their useful life.

Continuing with the problem of carbon capture and storage, Yu and Zhou. have extended novel methods, such as the experimental and modeling study of CO_2 storage, to foam coarsening kinetics in porous media. The findings shed light on the prediction of the foam structure in many applications, such as the foam-assisted enhanced oil recovery process and CO_2 geological sequestration. That is, in porous media, small bubbles are constantly consumed by large bubbles due to inter-bubble gas diffusion until most bubbles grow to the pore or throat size. In this study, it was demonstrated that the coarsening of edge bubbles dominated the foam coarsening process, showing a linear increase in the average area of edge bubbles with time in a steady-state growth state. In summary, the authors emphasize that, under the same experimental conditions, foams with a broader size distribution can exhibit a faster coarsening rate due to higher capillary pressure differences among the bubbles as the mass transfer driving force.

The final contribution by Huang et al. focuses on CO_2 conversion and utilization using tandem catalysts. This research advances the catalytic production of higher alcohols (HAs) as a promising path for converting CO_2 into value-added chemical products. However, the application is still limited by the low selectivity of HAs (less than 10%) on most catalysts. In this paper, the authors report a tandem catalyst consisting of Mn-Cu-K-modified iron carbide and CuZnAlZr catalyst. The modification of iron carbide with Mn, Cu, and K promoters improves the formation of HAs (13.5% Sel.), and the construction of tandem catalysts with CuZnAlZr can further enhance the catalytic performance. By examining different catalyst filling methods and the filling ratio of the tandem catalyst, it was found that a synergistic effect leads to a higher selectivity of HAs (15.5%), with about 40% of propanol and butanol among HAs. This work opens the door to facilitating CO_2 conversion and utilization toward useful products at large scales.

We hope that the readers will find this Research Topic to be a useful reference for this state-of-the-art research while also recognizing these five authors as emerging leaders in the field of CCUS.

Author contributions

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

Conflict of interest

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