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EDITORIAL

# Technoeconomic perspectives on sustainable $CO_2$ capture and utilization

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Limiting the rise of $CO_2$ (carbon dioxide) concentration in the atmosphere by capturing $CO_2$ from various emissions is a major challenge facing the world today. It is critical to address this challenge urgently for the sake of our present and future generations. Hence, the last decade has seen a huge increase in research related to CCSU (carbon capture storage and utilization). The International Conference on Carbon Dioxide Utilization (ICCDU) provides a vibrant multi-disciplinary discussion forum for leading academics, researchers, and practitioners to showcase their recent innovations in the capture, concentration, storage, utilization, and conversion of carbon dioxide. The first edition (ICCDU-1991) of this biennial conference series took place in Japan. Since then, it has been held at various venues in Europe, Asia, and America.

The one and only Singapore hosted the 13th edition (ICCDU XIII or ICCDU-2015) during July 5–9, 2015. The theme of ICCDU-2015 was materials, processes, and systems related to CCSU. ICCDU-2015 featured several plenary and keynote lectures by eminent speakers (including a Nobel Laureate) from around the world and a panel discussion involving academic, industry, and policy leaders from all continents. Attended by 340 delegates from 34 countries, ICCDU-2015 involved 330 oral and/or poster presentations. After a successful conference, we invited the delegates to submit full-length manuscripts related to their conference presentations. The manuscripts were submitted for peer reviews to *four* special issues on ICCDU-2015 in *Industrial & Engineering Chemistry Research*, *Catalysis Today*, *Journal of $CO_2$ Utilization*, and *Environmental Science and Pollution Research*.

This special issue features nine scientific contributions that present technoeconomic perspectives on and/or sustainability analyses of various conversion alternatives, process designs, and innovative materials related to CCSU. The issue begins with a broad supply chain perspective on CCSU. It then compares alternative processes and technologies for high-temperature capture, dry reforming, biofixation, biocatalysis, and mineralization.

In contrast to the other eight articles that evaluate specific processes and technologies, Naims (Naims 2016) analyzes the supply and demand of $CO_2$ as a feedstock. She reviews the industrial sources of $CO_2$ emissions, their benchmark capture costs, and potential S/U alternatives to predict the roles and relative importance of various $CO_2$ supply sources for the near-term (<10 years) and long-term (>10 years) scenarios. She concludes that the current $CO_2$ supply is more than adequate, even if no fossil fuels are used for power generation.

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The next two articles assess high-temperature sorbents for carbon capture. First, Sanna and Maroto-Valer (Sanna &Maroto-Valer 2016) calcinate $K_2CO_3$ and fly ash to synthesize several K-FA sorbents for chemisorbing $CO_2$. They show that adding 10 mol% $Li_2CO_3$ promotes both sorption and desorption due to a K-Li eutectic phase that promotes the diffusion of K and $CO_2$ into the sorbent matrix. Second, Zamboni et al. (Zamboni et al. 2016) demonstrate the synergistic effect of high-temperature sorption on steam-based biomass gasification in a fluidized bed of CaO-$Ca_{12}Al_{14}O_{33}$/Olivine to enhance hydrogen production and tar removal.

The remaining six works evaluate various carbon conversion technologies. First, Mondal et al. (Mondal et al. 2016) compare dry reforming of methane (DRM) with SRM (steam reforming of methane) for producing methanol via syngas. They develop, simulate, and evaluate a conceptual process for methanol synthesis via DRM (dry methane reforming). For a zero-cost $CO_2$ scenario, they find DRM to offer lower capital and operating costs compared to SRM.

The next three studies consider biofixation or biocatalytic electroreduction of $CO_2$. Dibenedetto et al. (Dibenedetto et al. 2016) evaluate two microalgae strains for producing biofuels, human food, animal feed, and chemicals. They conclude that the biofuels from such a microalgae cultivation cannot compete economically, unless a biorefinery concept is used to produce chemicals as well, and wastewater is used for nutrients. In the second study, Yadav et al. (Yadav et al. 2016) design and experiment with a small photobioreactor to capture $CO_2$ from the vent gas produced by a sulfur recovery unit at a plant site in Hazira (India). Using a consortium of microalgae, they successfully reduced the $CO_2$ content of the vent gas from 33 to 15 vol%, and subsequently used the biomass to produce biogas via anaerobic digestion. In the last study, Bajracharya et al. (Bajracharya et al. 2016) propose gas diffusion electrode (GDE) as a biocathode for the microbial catalysis of $CO_2$ electroreduction to produce acetate, ethanol, and butyrate. The GDE facilitates a continuous supply of $CO_2$ to the three-phase interface at the electrode to enhance mass transfer and promote CO2 reduction.

The last two contributions of this issue examine $CO_2$ mineralization. Yuen et al. (Yuen et al. 2016) critically evaluate 10 literature process designs for overcoming the slow natural weathering of silicate minerals. They suggest energy consumption, operational issues, and process economics as evaluation metrics, and recommend a mix and match approach to process design. Agrawal and Mehra (Agrawal &Mehra 2016) study the mechanism and kinetics of olivine dissolution using a naturally weathered dunite from an Indian source. They study the effects of salinity, temperature, and mineral loading, but cannot infer any definite trends due to the system complexity.

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## References

Agrawal AK, Mehra A (2016) Olivine dissolution from Indian dunite in saline water. Environ Sci Pollut Res 1–9. doi:10.1007/s11356-016-6774-2

Bajracharya S, Vanbroekhoven K, Buisman CJ, Pant D, Strik DP (2016) Application of gas diffusion biocathode in microbial electrosynthesis from carbon dioxide. Environ Sci Pollut Res 1–17. doi:10.1007/s11356-016-7196-x

Dibenedetto A, Colucci A, Aresta M (2016): The need to implement an efficient biomass fractionation and full utilization based on the concept of "biorefinery" for a viable economic utilization of microalgae. Environmental Science and Pollution Research, 1–10

Mondal K, Sasmal S, Badgandi S, Chowdhury DR, Nair V (2016): Dry reforming of methane to syngas: a potential alternative process for value added chemicals—a techno-economic perspective. Environmental Science and Pollution Research, 1–7

Naims H (2016) Economics of carbon dioxide capture and utilization—a supply and demand perspective. Environ Sci Pollut Res 1–16. doi:10.1007/s11356-016-6810-2

Sanna A, Maroto-Valer MM (2016): Potassium-based sorbents from fly ash for high-temperature CO2 capture. Environmental Science and Pollution Research, 1–11

Yadav A, Choudhary P, Atri N, Teir S, Mutnuri S (2016) Pilot project at Hazira, India, for capture of carbon dioxide and its biofixation using microalgae. Environ Sci Pollut Res 1–8. doi:10.1007/s11356-016-6479-6

Yuen YT, Sharratt PN, Jie B (2016) Carbon dioxide mineralization process design and evaluation: concepts, case studies, and considerations. Environ Sci Pollut Res 1–22. doi:10.1007/s11356-016-6512-9

Zamboni I, Debal M, Matt M, Girods P, Kiennemann A, Rogaume Y, Courson C (2016): Catalytic gasification of biomass (Miscanthus) enhanced by CO2 sorption. Environmental Science and Pollution Research, 1–14

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