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Editorial

CO_2 Capture and Sequestration

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CO_2 capture and sequestration (CCS) aims to capture carbon dioxide (CO_2) from CO_2 sources (e.g., fossil fuel power plants), separate the CO_2, and store it in suitable media. CO_2 can be captured using various technologies, including absorption, adsorption, cryogenic processes, and membrane gas separation [1]. Therefore, accurate selection, design, modelling and optimisation of the processes for CO_2 capture and the tuning of the material properties are essential. There are different methods used for CO_2 sequestration, e.g., (i) geological sequestration that injects different phases of CO_2 into the subsurface [2], (ii) oceanic storage that dissolves CO_2 into an ocean at different depths [3], (iii) the solid-phase reaction of CO_2 with metal oxides to produce stable carbonates with no risk of CO_2 release to the atmosphere [4], and others. The flow, transport, and reaction of CO_2 during CCS and other related matters, such as monitoring critical parameters, are also essential [5].

To address these points, a Special Issue (SI) of *Clean Technologies* has been organised to highlight the recent trends and innovative developments in CCS [6]. Thirteen (13) submissions were received, which underwent a rigorous peer review process. Two papers were declined at the peer review stage, and the remaining eleven papers [7–17] have now been published [6]. The published papers are also being compiled as an edited e-book to be published by MDPI. The papers [7–17] highlight several common and important issues.

Issues related to CCS project development and deployment have been considered by Marshall [7] and Veloso et al. [8]. Marshall [7] has identified that although CCS projects are essential to lower gas emissions, they have not achieved their desired objectives in Australia. To investigate the reasons for this failure, Marshall [7] undertook a historical and social study of the Gorgon gas project in Western Australia, considered one of the world's most significant CCS projects. The study has rightly concluded that CCS's social dynamics must be included in CCS project projections to enhance the accuracy of their expectations, without which the project projections are likely to miss their targets. Veloso et al. [8] emphasised that there are few commercial-scale CCS projects worldwide, and almost all are in the USA and China. Despite the many CCS pilot-scale projects planned in Europe, only two commercial-scale projects operate today. To help improve this situation, the authors have proposed a 'multicriteria regional-scale approach' that can help select the most promising locations in France to deploy CCS pilot-scale projects. Subsequently, the authors have assessed different aspects of CCS technology at the regional scale, including the key economic performance indicators of the CCS project. The authors have rightly concluded that the CCS projects should be located strategically close to potential CO_2 sources in case of the confirmation of proven resources.

Several fundamental issues concerning CCS have also been addressed in the SI. Pfennig and Kranzmann [9] considered cases where CO_2 is compressed to sequestrate it into deep geological formations. In this process, the corrosion of injection steel pipes can occur due to the contact of the metal with CO_2 and saline water in the geological formation. The published work is supported by the authors' laboratory experiments, which have evaluated corrosion kinetics on stainless steels $X_{35}CrMo_{17}$ and $X_5CrNiCuNb_{16\text{-}4}$ with approximately 17% Cr. The relationship between the corrosion rate and ionic species diffusion into the metal has been studied to determine the longevity of the chosen steels

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Citation: Das, D.B. CO_2 Capture and Sequestration. *Clean Technol.* **2024**, *6*, 494–496. https://doi.org/10.3390/cleantechnol6020025

Received: 27 December 2023
Accepted: 12 March 2024
Published: 16 April 2024

in a CCS environment. In the paper by Abidoye and Das [10], the effects of particle size, carbonation time, curing time and pressure on the efficiency of carbon storage in Portland cement mortar as the media for CCS have been investigated. The authors have shown how carbonation efficiency increases with decreased particle size using data generated in pressure chamber experiments. Overall, these authors show that carbonation efficiency increases with smaller-sized particles or higher-surface areas, carbonation time and higher pressure, but it decreases with hydration/curing time. Quaid and Reza [11] analysed deep eutectic solvents (DESs) for their carbon capture and biogas upgrade applications. In particular, they analysed how the presence of contaminants in biogas may affect the carbon capture by DESs. The behaviour of DESs under different temperatures, pressures, and influences from pollutants has been studied, which suggests that a complex interplay of variables must be understood when choosing DESs for CO_2 absorption for biogas uplifting.

This Special Issue also highlights how the captured CO_2 may be further used to synthesise value-added chemicals. Khokarale et al. [12] demonstrate that industrially important solvents, namely, dimethyl carbonate (DMC) and glycidol, could be synthesised in a combined process using glycerol-derived 1,3-dichloro-2-propanol and captured CO_2 via a metal-free reaction route under mild conditions.

The mathematical modelling applications in CCS have been demonstrated by Deschamps et al. [13] and Khudaida and Das [14]. Deschamps et al. [13] used conservation of mass and energy principles and equations of states to evaluate the performance of a vacuum temperature swing adsorption (VTSA) process for direct CO_2 capture from the air at an industrial scale. A parametric study on the effects of the main operating conditions has been undertaken to assess the performance and energy consumption of the VSTA. The developed approach considers how the lab-scale process could be upscaled to a larger industrial scale. In contrast to lab- or industrial-scale processes, Khudaida and Das [14] attempted to conduct a numerical study on the significance of injecting CO_2 into deep saline aquifers at the scale of geological formations. Several CO_2 injection scenarios and aquifer characteristics have been investigated to enhance current knowledge on the effects of the residual and solubility trapping of CO_2 on the sequestration mechanisms. For example, it was shown how the extent of subsurface heterogeneity increases the residual trapping of CO_2 in geological formations.

Finally, this Special Issue highlighted the critical issues relating to the techno-economic costing of CCS projects. Pieri and Angelis-Dimakis [15] reviewed the current approaches used to quantify CO_2 capture costs. It has been shown that with the existing knowledge in the literature, one can estimate capture costs based on the amount of CO_2 captured and the technologies used in CO_2 capture technology. In the paper by Szima et al. [16], it has been pointed out that increased levelized electricity costs within CCS projects are associated with significant energy penalties involved in CO_2 capture. Consequently, Szima et al. evaluated three CCS approaches that rely on integrated gasification combined cycles: (i) gas switching combustion (GSC), (ii) GSC with added natural gas firing to increase the turbine inlet temperature, and (iii) oxygen production pre-combustion that replaces the air separation unit with more efficient gas switching oxygen production reactors. This comparison has enabled the authors to identify the most promising solution for further development and exploitation in CCS. Reeve et al. [17] carried out a techno-economic analysis of three processes for hydrogen production from advanced steam reforming (SR) of bio-oil as an alternative route to hydrogen with bioenergy with carbon capture and storage (BECCS): conventional steam reforming (C-SR), C-SR with CO_2 capture (C-SR-CCS), and sorption-enhanced chemical looping (SE-CLSR). The analysis concluded that SE-CLSR is comparable to C-SR-CCS in terms of the levelized cost of hydrogen (LCOH).

Overall, it is evident that this Special Issue and the forthcoming e-book cover a diverse range of topics, including some of the most pressing concerns for CCS. I envisage that the authors of the published papers and I, as the guest editor of the SI, can motivate future directions and progress in CCS.

I appreciate the efforts of the authors and referees of all the accepted and declined papers. These contributions have made this Special Issue a true success. Finally, I acknowledge the Editorial Office for supporting this Special Issue and the edited e-book.

Conflicts of Interest: The author declares no conflict of interest.

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