Integrated approach to sea water brine valorisation and biomethane production using waste streams: techno-economic analysis and challenges

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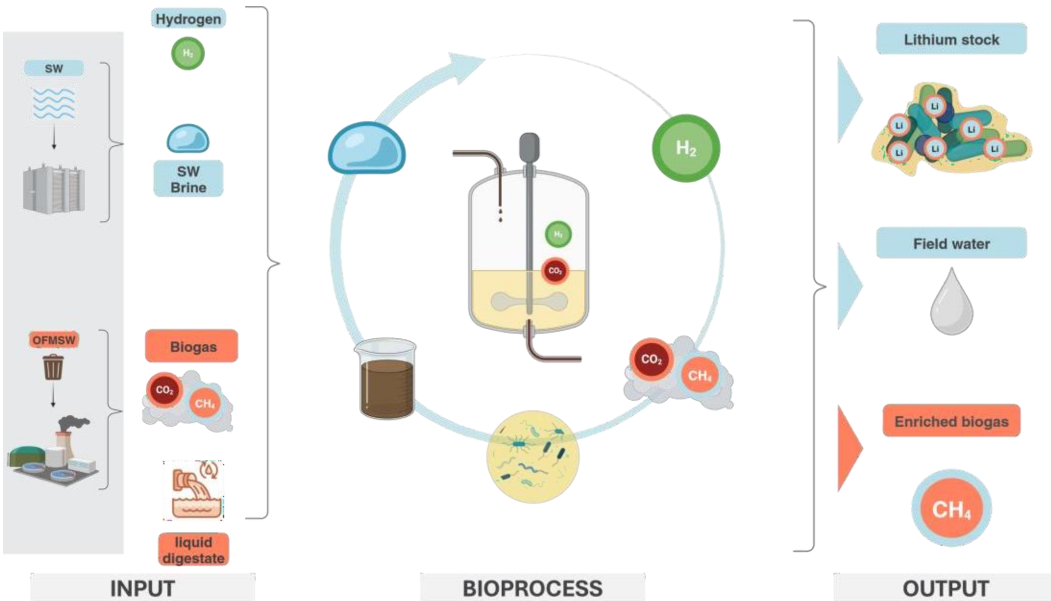
The recovery of valuable resources from waste streams is increasingly recognized for its environmental and economic benefits. This study focuses on resource recovery from desalination brine, addressing global waterscarcity challenges (The Sustainable Development Goals Report 2023). Desalinated water is a crucial supplement to natural freshwater sources, with reverse osmosis (RO) being the dominant process (Baudino, 2022). A significant issue with seawater desalination, especially RO, is the generation of concentrated brine, estimated at 124.5 million m^3/day globally. This brine is typically disposed of in coastal waters, posing environmental risks to marine ecosystems. Recovering metals like lithium and magnesium from desalination brine offers a sustainable solution. Lithium, essential for batteries in electric vehicles and electronics, is present in desalination brine, and efficient extraction technologies can meet the growing demand for renewable energy storage (U.S. Geological Survey, Mineral Commodity Summaries, January 2023). This study explores an innovative brine treatment approach involving a biomethanation unit using CO_2, digestate, H_2 from solar-powered electrolysis, and brine from SWRO plants as proposed in the perspective by Abdel Azim (2023). Various scenarios are evaluated through a comprehensive techno-economic analysis, considering technical and economic aspects. Despite being a pioneering effort, the study acknowledges limitations and the need for careful consideration of economic and environmental impacts for large-scale development. The process involves microbial biomass absorbing metals through biosorption and active transport, with potential metal precipitation due to organic matter in the digestate (Madeła, 2021). The findings aim to advance sustainable desalination practices and resource recovery, providing insights into the technical feasibility and economic viability of integrating biomethanation in brine treatment. The techno-economic analysis evaluates the proposed method against existing technologies, assessing operational efficiency and market competitiveness essential for commercial success (Morgante, 2022). The comparative aspect of this analysis is particularly enlightening, revealing how different technologiesstack up in terms of technical efficiency and economic feasibility. For instance, the comparison with emerging technologies such as nanofiltration, ionic exchange membranes, electrodialysis (Baudino, 2022) provides valuable insights into operational effectiveness, potential scalability, and economic viability, which are crucial for making informed decisions about technology adoption. In conclusion, the study reports a comprehensive techno-economic analysis that investigate the feasibility and limitations related to the scalability of biomethanation process for brine valorisation in a circular biobased approach, emphasizing a closed-loop system that maximizes the utilization of wastes as resources within the cycle. By comparing this innovative approach with other existing technologies, we aim to contribute significantly to sustainable desalination practices and open new pathways for resource recovery. This analysis aligns with global sustainability goals, highlighting the potential for capitalizing waste in an economically viable and environmentally sustainable manner.

Figure 1 Concept and circularity of the proposed process for brine treatment via biomethanation.



From the left to the right: 1) input of the bioprocess are respectively provided by sea water electrolysis producing hydrogen and brine and by anaerobic digestion process producing biogas and digestate used as feedstocks; 2) bioprocess consisting of a circular utilization of the gases and effluents from which biomethane enriched biogas, field water and lithium stocked by microbialcells are produced as output, 3). SW: Seawater, OFMSW: organic fraction municipal solid waste.

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