

Recent Advances in Membrane Technologies for Biogas Upgrading †

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Abstract: The pressing environmental and energy challenges of today are driven by the depletion of fossil fuels and a surge in greenhouse gas emissions, particularly carbon dioxide. This situation highlights the critical need for sustainable energy solutions. While carbon capture and storage (CCS) technologies offer hope, they face economic challenges at the scale needed to significantly reduce carbon dioxide emissions. Biogas, produced mainly through the anaerobic digestion of various biomass sources like agricultural waste, municipal solid waste, and wastewater, presents a renewable alternative. Composed largely of methane and carbon dioxide, biogas can be upgraded to bio-methane, serving as an eco-friendly replacement for natural gas. Technological advancements, particularly in membrane separation, have made biogas purification more efficient and cost-effective. Anaerobic digestion, a key process in biogas production, breaks down organic matter into simpler compounds, which are then transformed into gases like methane and carbon dioxide. The composition of biogas depends on the feedstock and digestion conditions, with methane being a valuable but challenging component to separate due to its greenhouse gas properties. Several purification technologies have been developed, including absorption, adsorption, cryogenic separation, and membrane separation, each with unique benefits and drawbacks. Membrane separation is particularly promising for its environmental benefits and scalability. However, the biogas industry faces challenges, especially in developing countries, due to high costs and limited research and development. Overcoming these obstacles requires collaboration among various stakeholders. Looking ahead, the future of biogas technology is bright, with advances in membrane materials and integrated refining processes. Integrating biogas into sectors like waste management and agriculture is crucial for its development and for meeting global renewable energy goals. Biogas technology not only reduces dependence on fossil fuels but also plays a vital role in the transition to sustainable energy.

Keywords: Biogas; Anaerobic Digestion; Gas Permeation Processes; Membrane Separation