# Interplay of Material and Cycle Design in a Vacuum-Temperature Swing Adsorption Process for Biogas Upgrading

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**Abstract :** Natural gas is a major energy source in the current global economy, contributing to roughly 21% of the total primary energy consumption. Production of natural gas starting from renewable energy sources is key to limit the related CO2 emissions, especially for those sectors that heavily rely on natural gas use. In this context, biomethane produced via biogas upgrading represents a good candidate for partial substitution of fossil natural gas. The upgrading process of biogas to biomethane consists in (i) the removal of pollutants and impurities (e.g. H2S, siloxanes, ammonia, water), and (ii) the separation of carbon dioxide from methane. Focusing on the CO2 removal process, several technologies can be considered: chemical or physical absorption with solvents (e.g. water, amines), membranes, adsorption-based systems (PSA). However, none emerged as the leading technology, because of (i) the heterogeneity in plant size, ii) the heterogeneity in biogas composition, which is strongly related to the feedstock type (animal manure, sewage treatment, landfill products), (iii) the case-sensitive optimal tradeoff between purity and recovery of biomethane, and iv) the destination of the produced biomethane (grid injection, CHP applications, transportation sector). With this contribution, we explore the use of a technology for biogas upgrading and we compare the resulting performance with benchmark technologies. The proposed technology makes use of a chemical sorbent, which is engineered by RSE and consists of Di-Ethanol-Amine deposited on a solid support made of γ-Alumina, to chemically adsorb the CO2 contained in the gas. The material is packed into fixed beds that cyclically undergo adsorption and regeneration steps. CO2 is adsorbed at low temperature and ambient pressure (or slightly above) while the regeneration is carried out by pulling vacuum and increasing the temperature of the bed (vacuum-temperature swing adsorption - VTSA). Dynamic adsorption tests were performed by RSE and were used to tune the mathematical model of the process, including material and transport parameters (i.e. Langmuir isotherms data and heat and mass transport). Based on this set of data, an optimal VTSA cycle was designed. The results enabled a better understanding of the interplay between material and cycle tuning. As exemplary application, the upgrading of biogas for grid injection, produced by an anaerobic digester (60-70% CO2, 30-40% CH4), for an equivalent size of 1 MWel was selected. A plant configuration is proposed to maximize heat recovery and minimize the energy consumption of the process. The resulting performances are very promising compared to benchmark solutions, which make the VTSA configuration a valuable alternative for biomethane production starting from biogas.

**Keywords :** biogas upgrading, biogas upgrading energetic cost, CO2 adsorption, VTSA process modelling
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