Ammonia-based systems integrated with fuel cells for electrical power generation

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As Europe intensifies its shift toward sustainable and diversified energy sources, ammonia is gaining attention as a promising liquid carrier for large-scale hydrogen transport. Its appeal lies in its carbon-free composition, affordability, and a well-established industrial production chain. Ammonia can be utilized in two main ways: directly in fuel cells (FCs) or indirectly through thermal decomposition to extract hydrogen. Direct use in fuel cells is limited by catalyst performance, ammonia crossover, NO emissions, and start-up and durability issues—particularly in solid oxide fuel cells (SOFCs). Thermal decomposition, meanwhile, is energy-intensive, requiring high temperatures (850–950°C) and efficient hydrogen separation for downstream use. A promising strategy involves integrating ammonia cracking systems with fuel cells, leveraging waste heat and partial energy feedback to enable self-sustaining, auto-thermal operation (Fig. 1). This could reduce energy consumption, material use, and emissions. However, optimizing such systems involves navigating a complex set of variables, including fuel cell type, system layout, and the technologies used for decomposition and gas separation. This study employs process simulations with Aspen Plus and Aspen Adsorption to evaluate advanced configurations of ammonia-powered systems. It investigates the energy performance of designs combining low- and high-temperature PEM fuel cells and SOFCs, with a focus on heat recovery and overall system efficiency. A sensitivity analysis further explores key parameters like fuel cell performance, heat integration, and hydrogen/nitrogen separation efficiency. The main results in terms of overall efficiency and auto-thermality of the systems is reported in Fig. 1.

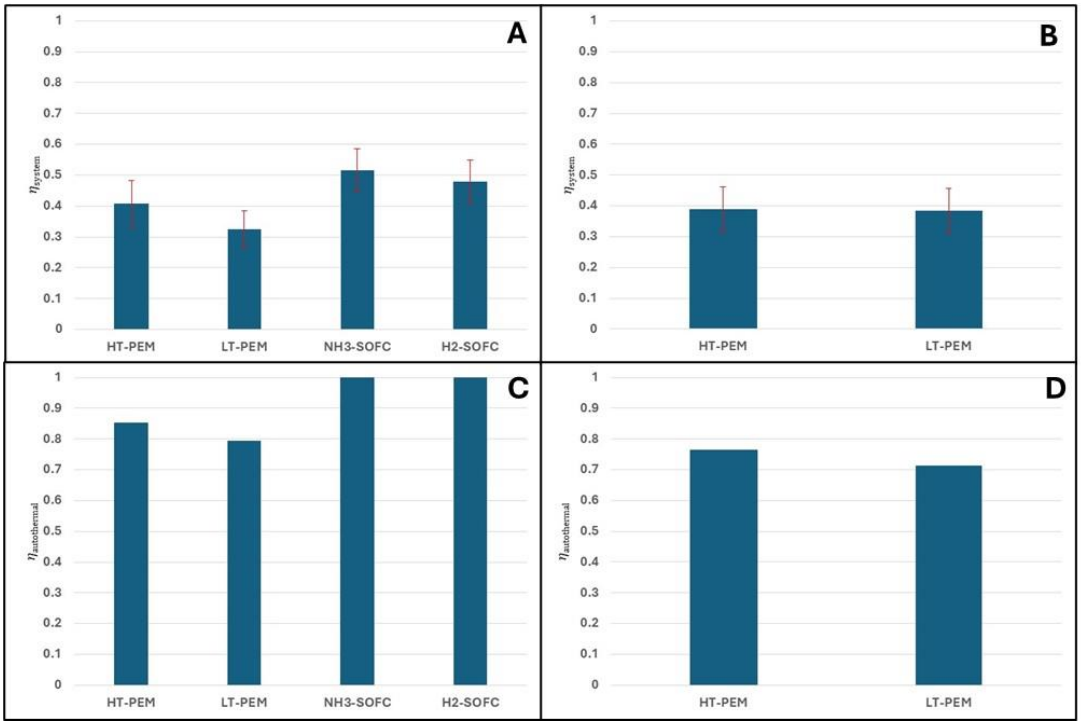

Fig. 1. Integrated systems efficiency with (B) and without (A) PSA unit for N2/H2 separation. Autothermality of integrated systems with (D) and without (C) PSA unit for N2/H2 separation.