Evaluation of fuel options for marine MCFC-integrated carbon capture systems

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Reducing carbon emissions from maritime transport is increasingly recognized as a fundamental step toward achieving global climate goals. The shipping sector, which is responsible for a considerable portion of worldwide CO_2 emissions, continues to rely heavily on carbon-intensive fossil fuels. The slow pace of adoption of zero-carbon propulsion technologies, combined with the long operational lifespans of vessels, makes full decarbonization of the fleet a complex and long-term objective. In the near to medium term, therefore, alternative strategies are essential to bridge the gap and lower emissions from existing ships and propulsion systems.

One promising pathway involves the integration of onboard carbon capture systems, which allow emissions to be significantly reduced without requiring disruptive changes to ship architecture or engine technology. In this context, Molten Carbonate Fuel Cells (MCFCs) are emerging as a viable solution, offering the unique advantage of producing electrical energy while simultaneously separating carbon dioxide from the exhaust stream. Their ability to operate efficiently under marine conditions, combined with modular design and compatibility with varying CO_2 concentrations, makes them well-suited for application in the maritime environment, especially for retrofitting purposes.

This research explores a novel system layout that incorporates MCFCs to enhance the capture of CO_2 emissions onboard ships. The study goes beyond generic system analysis by focusing on how the selection of fuel influences the performance and feasibility of MCFC-based carbon capture. A comparative assessment is conducted across a range of marine fuels: Liquefied Natural Gas (LNG), biomethane (bioLNG), methanol, biomethanol, as well as grey and green ammonia. These fuels differ widely in their carbon intensity, supply chain maturity, and compatibility with energy systems.

The investigation considers multiple factors, including the thermodynamic performance of the MCFC system with each fuel type, integration challenges, and the overall CO_2 capture efficiency achievable. Operational implications, and the potential for supporting the broader transition to low-carbon maritime operations are also examined. The results offer a comprehensive perspective on how fuel choice affects both the environmental and technical performance of MCFC-integrated capture systems.

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