Decarbonization of the maritime sector through fuel shift and carbon capture technologies

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The shipping sector is facing increasing pressure to reduce its environmental impact, particularly in light of the new European Union's regulations. Maritime transport has been, indeed, included in a series of decarbonization initiatives - most notably the extension of the EU Emissions Trading System (ETS) and the introduction of the FuelEU Maritime - with the goal of reaching net-zero emissions by 2050.

Given the current regulatory landscape, this work investigates the potential for integrating decarbonization technologies onboard ships by exploring two promising approaches: the use of renewable fuels and the deployment of onboard post-combustion carbon capture (OCC) systems, with the aim of understanding their effectiveness, tecno-economic feasibility and regulatory alignment.

In the context of alternative fuels, Fatty Acid Methyl Ester (FAME) and Hydrotreated Vegetable Oil (HVO) are selected for their compatibility with conventional marine engines. These fuels are studied both pure and in blends with the fossil fuels currently in use, namely Marine Gas Oil (MGO) and Heavy Fuel Oil (HFO) to characterize their physical and rheological properties and understand potential impacts on fuel bunkering, storage, and handling systems and the retrofitting measures needed.

In parallel, a shipboard post-combustion carbon capture system is modeled, choosing as reference case study a 4-stroke engine vessel powered with MGO. The study considers operational constraints such as space availability, integration with existing onboard systems and, above all, energy requirements. As post combustion technology, an absorption-based process is chosen for its relatively high TRL and proven effectiveness, with particular focus on conventional amine-based solvents, specifically MEA, MDEA, PZ and their blends. Moreover, to cope with the energy constraint, it is also chosen to consider as the only energy source available the heat recovered from the flue gas, with the idea of investigating the achievable CO_2 recovery in these conditions.

Preliminary results indicate that renewable fuels, from a rheological point of view, behave similarly to fossil ones, however some changes in physical properties may necessitate adjustments in the fuel supply line. In the case of OCCS, the energy constraints are decreasing the achievable CO_2 recovery and thus the suitable amines to operate the process, making further investigation necessary.

These findings will serve as a basis for a comprehensive understanding of the respective challenges and potentiality of these technologies, and for future comparative assessments to identify the most viable pathways for reducing GHG emissions of the maritime sector in line with EU decarbonization goals.

Keywords: Shipping Decarbonization, Renewable Fuels, On board Carbon Capture