

Thermomechanical and Sustainability Assessment of LNG and LH2 Membrane Tank Designs

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As the maritime sector moves toward cleaner energy sources, identification of effective insulation for Liquefied Natural Gas (LNG) and Liquid Hydrogen (LH2) carriers takes on greater importance. These systems must handle structural loads, manage heat transfer at cryogenic temperatures, while also meeting sustainability benchmarks. The purpose of this abstract through advancing to a previously established conceptual framework for sustainability assessment of multi-material membrane tanks, is to provide a detailed trade-off between different membrane tank designs integrating advanced thermomechanical simulations.

Central focus of this work is the thermomechanical simulation of different panel designs where mechanical loads and cryogenic temperature gradients affect both structural integrity and thermal performance. These different designs are produced based in the available literature and design solutions identified through previous sustainability assessment. By detailed simulations, the results of changes in layer thickness, material choices, or overall configuration can alter stress distribution, deformation, and boil-off rates. Our findings show not only how trade-off studies are essential but also that detailed thermomechanical performance have to be taken into account when examining the feasibility of design solutions.

By merging thermomechanical modelling with sustainability metrics, it becomes possible to engineer cryogenic insulation solutions that meet strict structural and thermal demands while remaining economically and environmentally viable. This integrated methodology is especially useful to the maritime sector, where there is increasing pressure to cut emissions and improve fuel storage efficiency. Our findings highlight a direct route to more robust, resource-efficient LNG and LH2 storage systems, showing how early-stage consideration of sustainability and thermomechanical response can shape innovative and responsible design strategies.

Keywords: Trade-off, Thermomechanical simulation, Liquid Hydrogen, Sustainability, Membrane Tank, Multi-Material Design