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Energy systems selection for maritime shipping

Selection methodology ensuring compliance with FuelEU regulations

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Context & Objectives

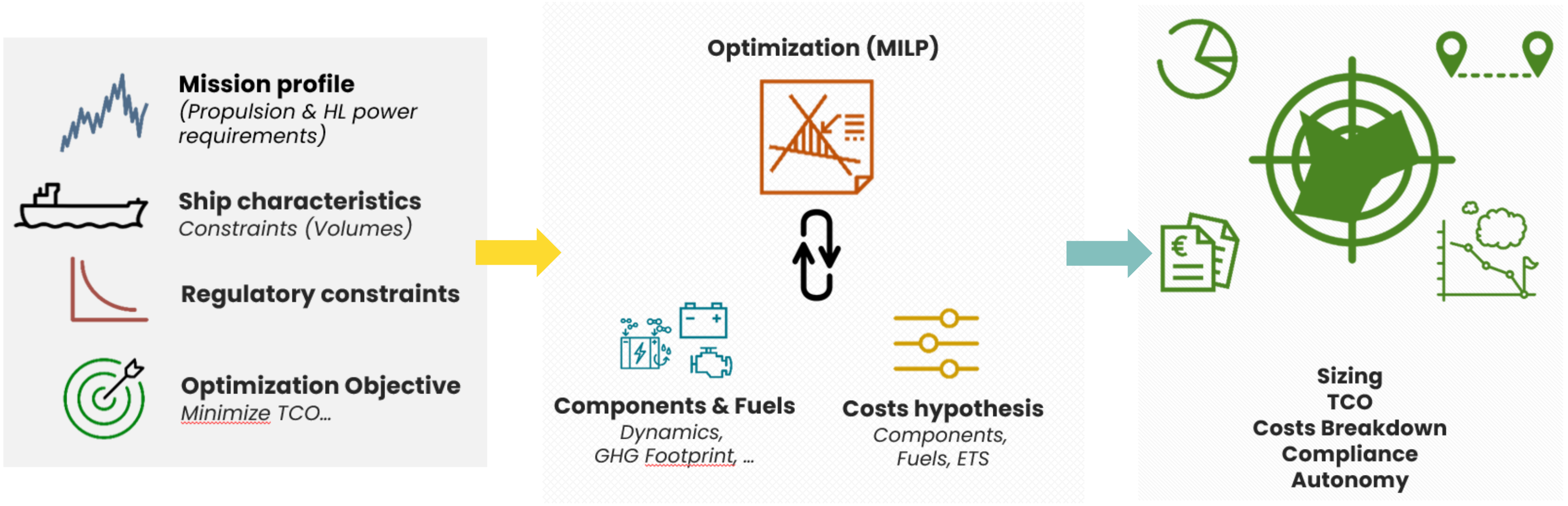
Supporting the identification of best trade-offs of **energy/power systems** and **alternative fuels** for hybrid ships in order to ensure long lasting **compliance** with **FuelEU Maritime regulations** that:

- Minimize Total Cost of Ownership: CAPEX and OPEX, penalties, Emissions Trading System (ETS)
- Ensure operational requirements and constraints: Autonomy, on-board volume, and system dynamics

Methodology

Starting from costs hypothesis, a mission profile and ship constraints, an optimization by mean of Mixed Integer Linear Programming (MILP) provide the following indicators for concurrent energy systems architecture:

- Minimized Total Cost of Ownership
- Sizing of hybridized energy/power systems and autonomy
- Yearly fuel blending ratio (fossil and renewable), that satisfies FuelEU regulations over ship's lifetime



Mission profile
(Propulsion & HL power requirements)

Ship characteristics
Constraints (Volumes)

Regulatory constraints

Optimization Objective
Minimize TCO…

Optimization (MILP)

Components & Fuels
Dynamics, GHG Footprint, …

Costs hypothesis
Components, Fuels, ETS

Sizing
TCO
Costs Breakdown
Compliance
Autonomy

Applying this process on a variety of costs hypothesis allows studying sensitivity and reliance of energy systems architectures, supporting decision makers and maritime shipping decarbonisation.

Example Use-Case

A 300m bulk carrier, 14 days mission profile, stable fossil fuels price.

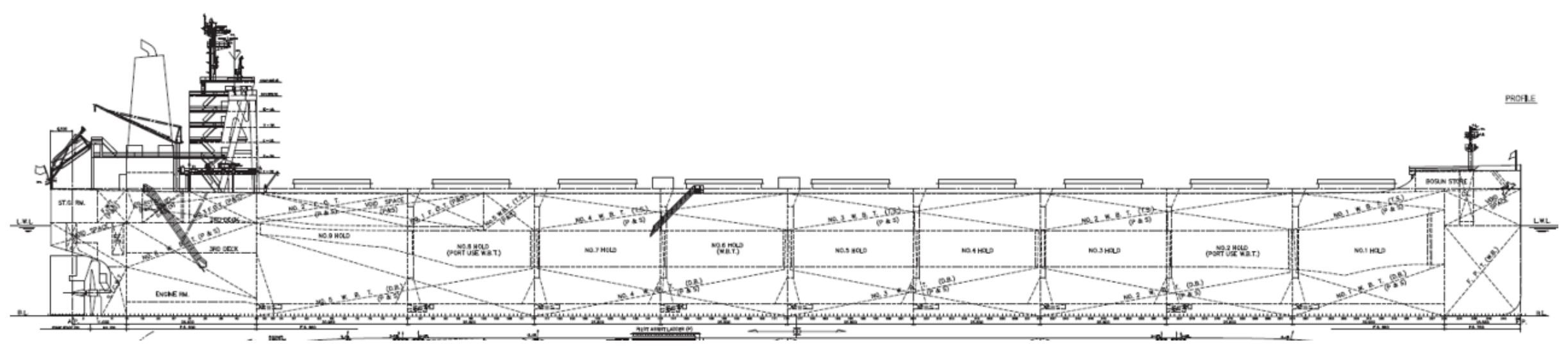
What technologies (batteries, fuel cells) and fuel blending (fossil Diesel, renewable e-Fuels) strategy overtime, compared to the Business as Usual case (BAU) with MDO Genset ?

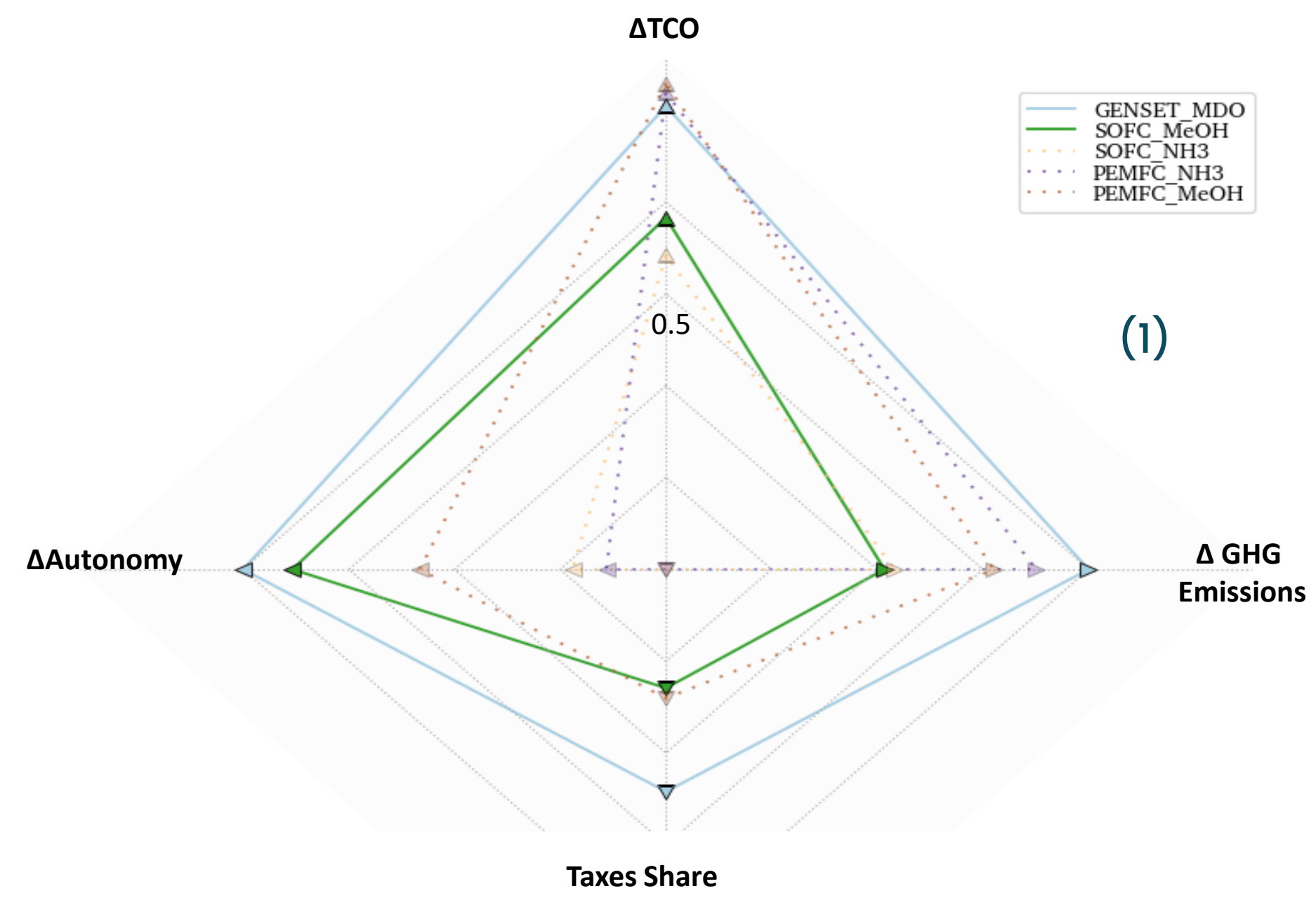
The use of fossil marine diesel in the BAU, is very sensitive to carbon price changes. The share of ETS and FuelEU penalties accounts for 45 to 75% of the TCO over the ship's lifetime, depending on the ETS hypothesis. The other studied systems show better resilience to carbon prices, as they include a share of renewable fuel overtime :

Figure (1) shows, with the study hypothesis, that the use of a high temperature fuel cell (SOFC) fed with methanol (MeOH) performs generally better than the other configurations, in terms of TCO and autonomy. Figure (2) depicts in this case the fossil methanol share in the fuel blending that satisfies the EU regulations, overtime.

Figure (3) presents the power and battery requirements function of the installed systems. Due to their low dynamics, high temperature fuel cells (SOFC) require more battery storage for the system to support peak loads and improve system efficiency.

Figure (4) shows that the use of any alternative fuel will require much more volume (due to tanks outer volume and fuels lower energy density) to achieve reasonable autonomy.





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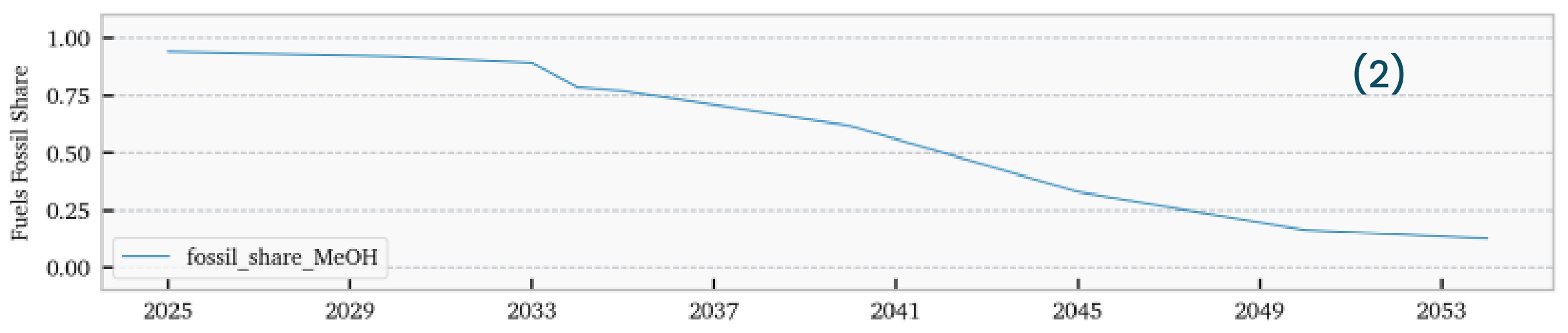

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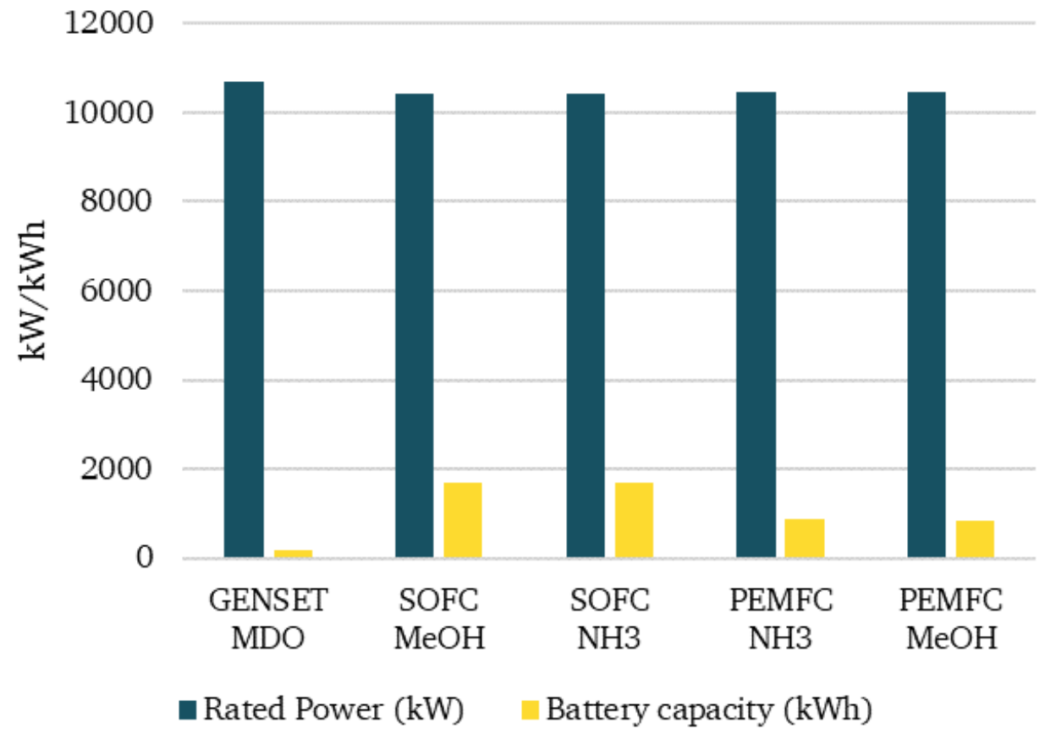

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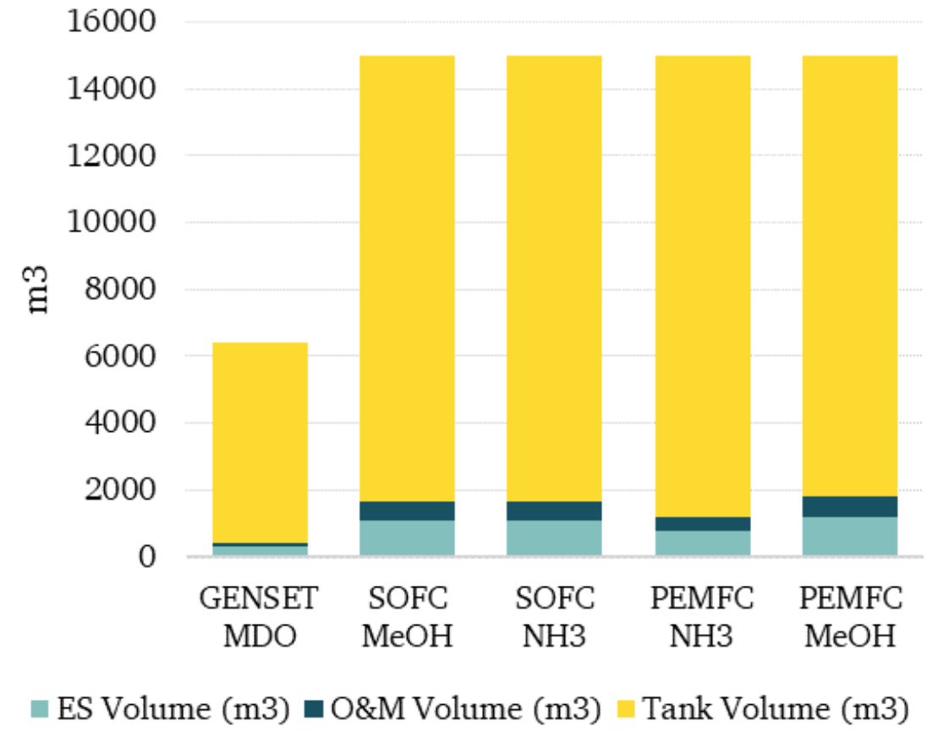

(4)

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