MARITIME FUTURE FUELS **Overview**

The following information provides an overview of the maritime future fuels picture for interest. This is a non-exhaustive list of considerations, and the cost of each option, relative to LSFO or MGO, is not a feature of this analysis.

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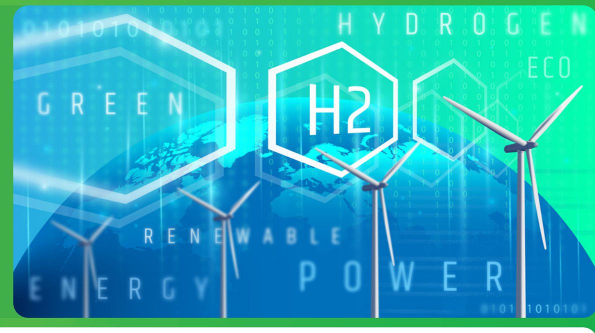
Fuel	Overall GHG reduction potential* – life cycle analysis considerations: Tank to Wake (TtW)	Overall GHG reduction potential* – life cycle analysis considerations: Well to Wake (WtW)	Challenges to be overcome	Other considerations
LNG	12 to 28%	8 to 22% - depending on the natural state, production process and distance to market.	While we have an abundant supply of LNG, bunkering infrastructure is currently limited in Australia. Methane slip, although variable, is an ongoing issue that can limit the TtW effect. Further decarbonisation of LNG possible via carbon capture and storage (CCS) however is currently very costly.	A mature and established marine fuel in use around the world. Can provide the foundation via the ongoing use of established infrastructure for future application of bio-LNG and synthetic LNG which can result in further significant reductions on a WtW basis.
Methanol	15 to 20%	WtW is highly dependent on the energy source used in its manufacture. Currently, the vast majority is produced using LNG, and therefore possesses a similar WtW profile.	Production at a scale required to supply maritime industry. Lack of established distribution and supply infrastructure for bunkering.	Methanol is a widely used and well understood substance, which is already in use as a marine fuel. As with LNG, the development of foundation use of methanol produced using non-renewable energy will assist in the establishment of a market and the necessary infrastructure for future application of methanol produced using renewable energy, which can result in further significant reductions on a WtW basis. IMO regulatory work on the use methanol as fuel is well advanced. WtW profile is very sensitive to production process and feedstock and to achieve significant emissions reductions, methanol needs to be produced using renewable energy.
Biofuels	Limited TtW GHG reduction due to the similar carbon content to fossil fuels.	WtW emissions reduction can be substantial, but it is a complex picture which is highly dependent on the feedstock, production process and supply chain.	Due to the complexity relating to feedstocks in particular, (e.g. demand for dedicated biofuels crops leading to deforestation), and lack of reliable certification that assesses the full lifecycle of biofuels production, it can be difficult to understand the genuine carbon reduction credentials of the range of biofuels products. Advanced biofuels, or those manufactured using various waste streams (as opposed to dedicated crops) provide the least risk of indirect impacts that could result in higher WtW emissions compared to fossil fuels. Advanced biofuels are not currently produced at the scale necessary to supply the maritime industry.	As a drop in solution, biofuels can utilise the existing supply and distribution network and be used in marine diesel engines with minimal modifications required. If scale and supply chain issues can be addressed, advanced biofuels have the added benefit of contributing to the circular economy.
Hydrogen	100%	Benefits from hydrogen as marine fuel are derived when hydrogen can be produced from renewable energy such as solar, wind or hydro power. While the combustion of hydrogen via a fuel cell produces water, it takes significant energy to power the electrolysis process to generate hydrogen.	Very different properties compared to conventional fuels requiring different safety/handling approach. For example, hydrogen is stored as a cryogenic liquid at very low temperature (-253C) Address concerns relating to intrinsic safety of hydrogen resulting from its broad flammability range. Development of technical standards, crew competency and safe handling regulations including bunkering. Low energy density (per volume) and may result in limited range and/or impact on available cargo space. Lack of any distribution and supply infrastructure.	Hydrogen is a highly versatile substance that can be used very effectively for energy storage either in its pure form or within a carrier such as ammonia or methanol. Hydrogen is an efficient energy carrier per weight, but inefficient per volume.
Ammonia	100%	Benefits ammonia as marine fuel are derived when it can be produced from renewable energy such as solar, wind or hydro power. Additional energy required to synthesise hydrogen and nitrogen.	Address concerns relating to toxicity and the need for the development of technical standards for use as fuel, crew competency and safe handling regulations including bunkering. Potential for NOx generation during combustion. Further development required for solid oxide fuel cell (SOFC) which would avoid the need for hydrogen reforming and purification.	Ammonia fuelled engines are currently under development. Energy density (per volume) much greater than hydrogen, with similar production costs. Widely traded and utilised commodity for a wide range of applications. Storing, loading and unloading is proven technology and there already exists a regulated storage distribution and supply infrastructure which could be adapted for the purpose of bunkering. Ability to store 1.5 times more hydrogen in ammonia than pure hydrogen and in comparison to other hazardous substances, Ammonia is relatively benign.



*Compared to MGO/LSFO

LSFO = Low Sulphur Fuel Oil | MGO = Marine Gas Oil | SOFC = Solid Ocide Fuel Cell | NOx = Nitrogen Oxide | LNG = Liquefied Natural Gas | CCS = Carbon Capture and Storage