THE ROLE OF BIO-LNG IN THE DECARBONISATION OF SHIPPING

REPORT KEY FINDINGS

SEA-LNG

NANYANG TECHNOLOGICAL UNIVERSITY SINGAPORE

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INTRODUCTION

There is growing interest in understanding the decarbonisation pathway offered by LNG. Building on the analysis done by CE Delft in 2019 on the availability of bio and synthetic methane, SEA-LNG commissioned this study on the role of bio-LNG in the decarbonisation of shipping.

Investment in the LNG pathway is growing. LNG as a fuel is dominating the orderbook of larger ships and – according to Clarkson Research - orders for LNG dual-fuel vessels total 298 or 38% of all tonnage ordered so far in 2022.

Bio-LNG represents the next phase of the LNG pathway, enabling shipping to meet the 2030 and 2050 GHG emissions reductions targets mandated by the International Maritime Organisation (IMO). The 2019 CE Delft study underlined the potential of bio-LNG at that time and this study brings that information up to date. The research was conducted and co-funded by the Maritime Energy and Sustainable Development Centre of Excellence (MESD CoE), Nanyang Technological University Singapore. It aims to answer questions around fuel availability, cost, lifecycle emissions and logistics and provide an overview of the applicability of bio-LNG as marine fuel. It also explores whether LNG and bio-LNG can provide a realistic pathway for the shipping industry to achieve GHG emission reduction targets in a sustainable manner.

The decarbonisation of shipping will require the use of multiple low and zero carbon fuels. Every fuel has its own individual, but similar, pathway to net zero. When assessing decarbonisation options for the maritime sector it is essential that each pathway is evaluated, not simply the destination. It is crucial that decision making is guided by accurate information that assesses each alternative fuel pathway on a like-for-like and full life-cycle basis (Well-to-Wake).

The viability of the LNG pathway depends on the volumes of bio-LNG and renewable synthetic LNG (or e-LNG) that become available to the shipping industry, and the cost of these fuels in comparison to other zero or low carbon fuels. The findings from this study provide reliable, independent insight on both availability and cost.

Bio-LNG can make a major contribution to maritime decarbonisation

- Liquefied biomethane, or bio-LNG, produced from sustainable biomass resources has the potential to meet a significant proportion of future shipping energy demand, even when taking into account growing demand for biomass from other sectors such as wood and paper production, industrial feedstocks, heat and, power generation, aviation and heavy-duty road transportation.

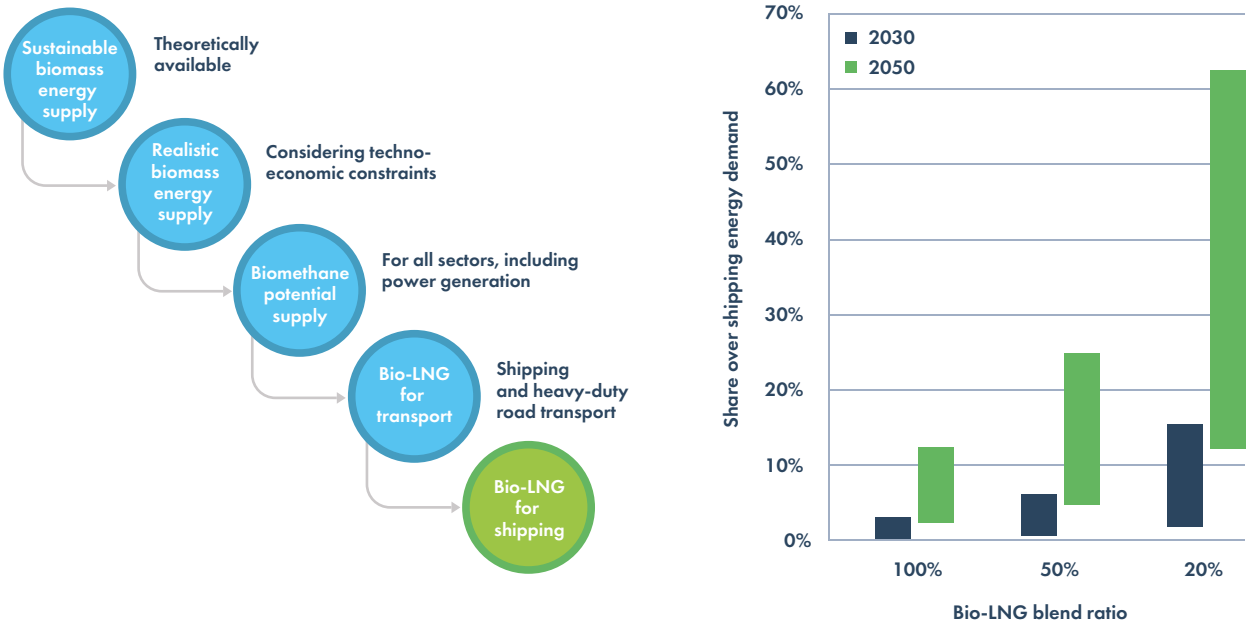

Figure 1 - Scheme for the evaluation of bio-LNG availability for shipping (left) and potential availability of bio-LNG for shipping sector in 2030 and 2050 over total shipping energy demand, with different blending rates with fossil LNG (right)

- Bio-LNG has the potential to meet up to 3% of the total energy demand for shipping fuels in 2030 and up to 13% in 2050.
- If it is considered as a drop-in fuel, blended with fossil LNG, bio-LNG could cover up to 16% and 63% of the total energy demand in 2030 and 2050, respectively, assuming a 20% blending ratio.
- Consequently, bio-LNG has the potential to be a viable drop-in biofuel that can be blended with fossil LNG to comply with IMO decarbonisation targets for 2030 and 2050.

Bio-LNG is among the cheapest sustainable alternative marine fuels by 2050

- The average cost for delivered bio-LNG is around 30 $/GJ today and is forecast to decline by 30% to approximately 20 $/GJ by 2050 driven mainly by the reduced cost of producing biomethane in large-scale anaerobic digestion plants.

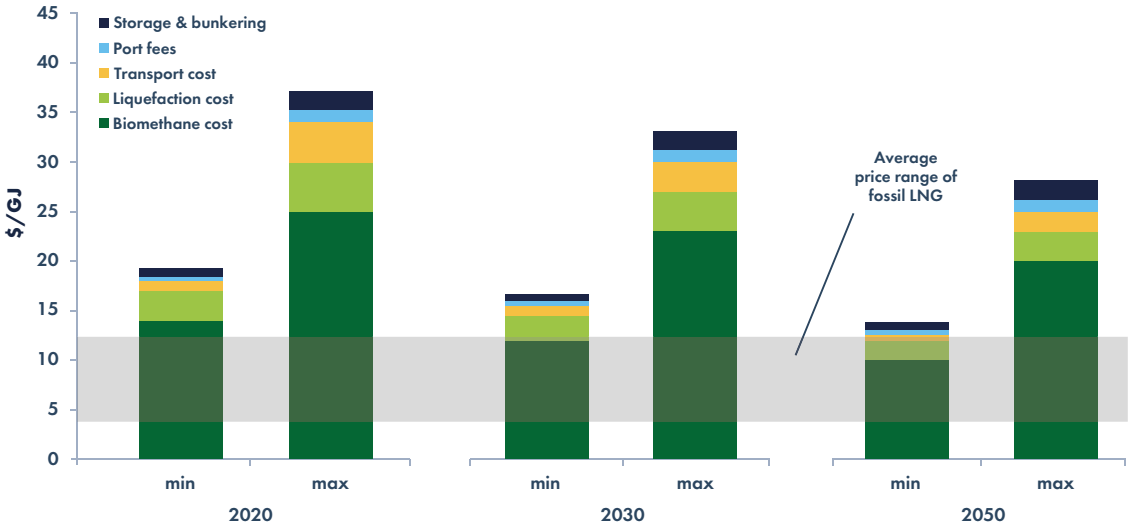

Figure 2 - Bio-LNG from anaerobic digestion total cost range in 2020, 2030 and 2050, compared with fossil LNG bunker price (range)

- Biomethane production accounts for around 70% of the overall cost of bio-LNG to shipowners, liquefaction and transport accountable for another 20%, while bunkering and port fees add up to the final 10%.
- Bio-LNG is among the most cost-effective alternative marine fuels, cheaper than biomethanol and electrofuels, including e-ammonia and e-methanol.

Gasum delivering Bio-LNG to the MV ISLAND CONTENDER on 14th Sep 2022

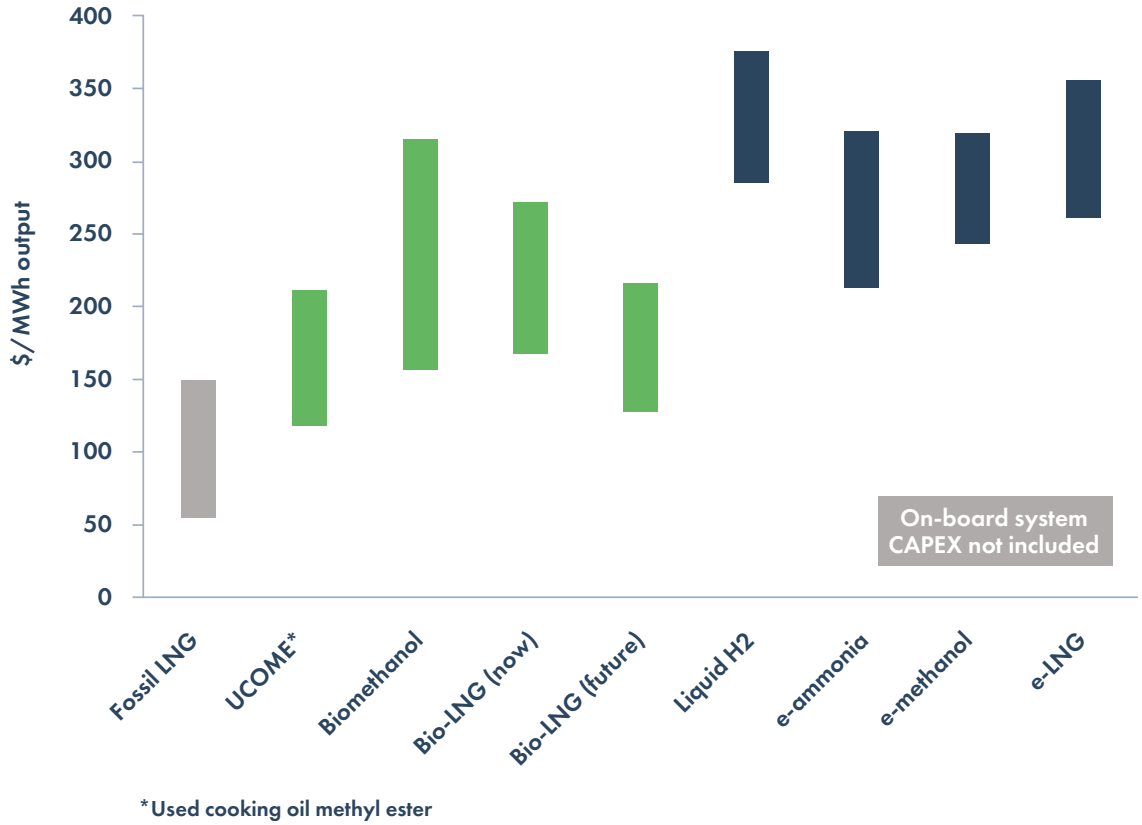

Figure 3 - Alternative fuels energy cost comparison, per unit of output energy from the engine. It includes transport and bunkering costs (bio-LNG and e-LNG transport cost is based on fossil LNG, thus implying the use of existing infrastructure). Assumed engine conversion efficiency 45% (50% for liquid hydrogen used in a fuel cell) (Note, the higher and lower ends of the spectrum represent 2030 and 2050 costs, respectively.)

Bio-LNG reduces GHG emissions by up to 80% compared to marine diesel

- In general bio-LNG can reduce GHG emissions by up to 80% compared to marine diesel if methane leakage in the production process and on-board methane slip are minimised.
- In the specific case of bio-LNG produced from anaerobic digestion of manure, if avoided emissions are considered, then bio-LNG can achieve negative emissions ranging from ranging from minus 121% to 188% compared with marine diesel.

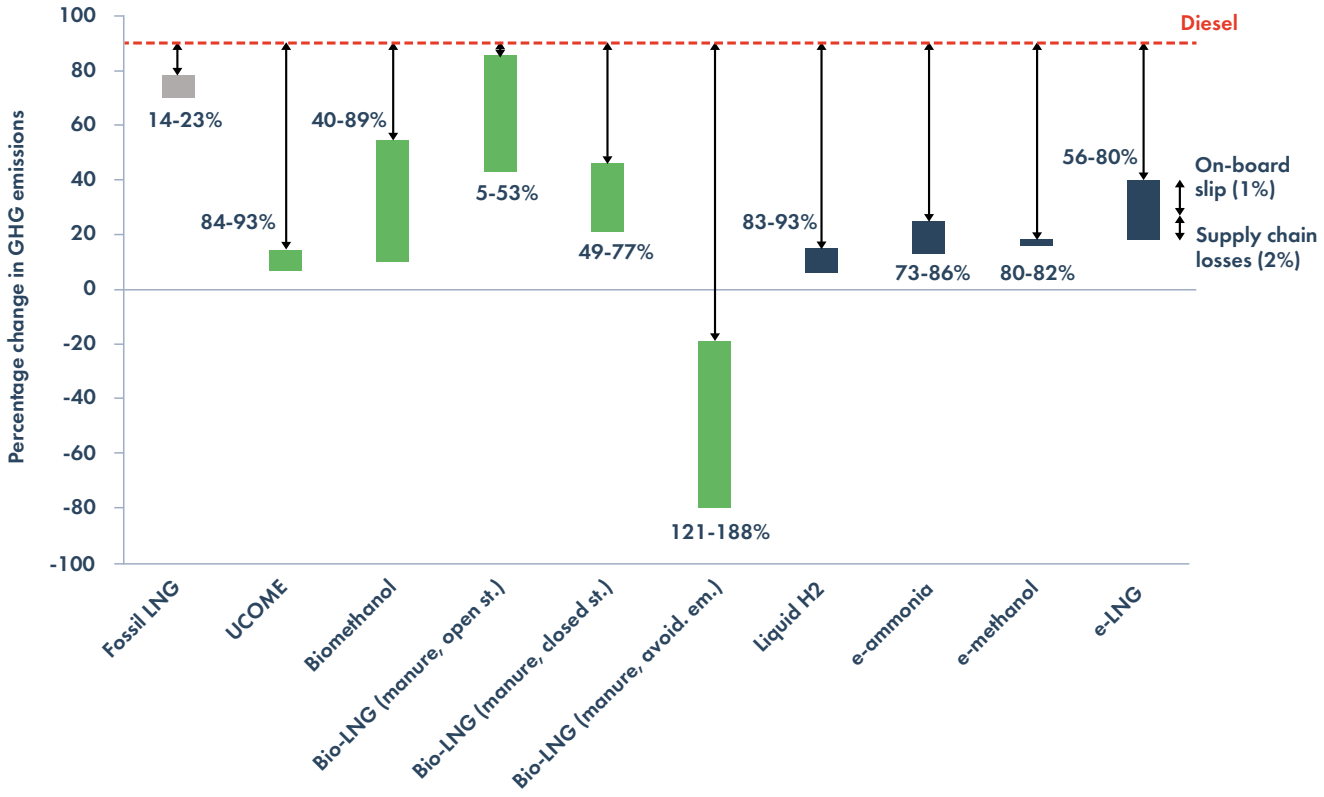

Figure 4 - Well-to-wake GHG emissions of alternative fuels compared to diesel. Includes emissions during fuel production and on-board emissions. Electrofuels are produced with wind energy and their cost range is estimated for 2050.

Bio-LNG benefits from existing LNG infrastructure, reducing logistics costs

- The use of fossil LNG as a marine fuel is an established, mature technology, with many LNG-fueled ships in operation.
- Bio-LNG can be used as drop-in fuel in existing LNG-fueled engines and can also be transported, stored and bunkered in ports using the existing LNG infrastructure.
- The lowest costs are achieved when biomethane is injected into the gas grid and virtually transported to liquefaction plants and LNG terminals using the existing infrastructure and Green Gas Certificates or Biomethane Guarantees of Origin for trading.

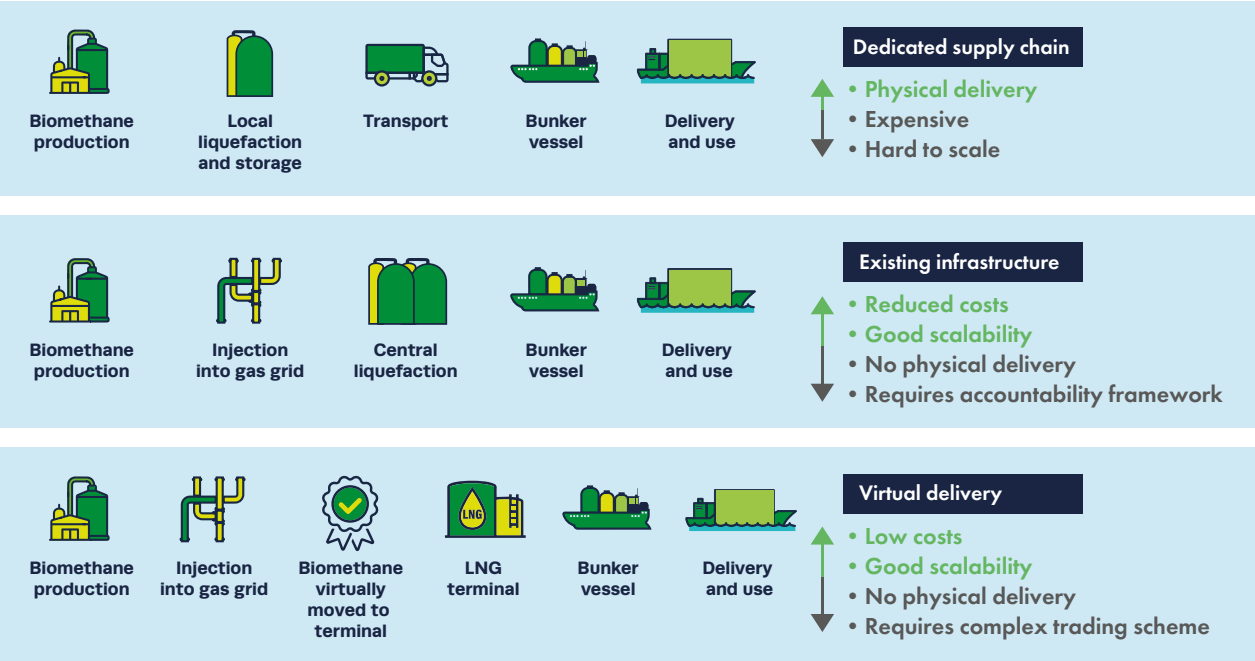

Figure 5 - Different possible configurations for bio-LNG supply chain for maritime transport with pros and cons

Bio-LNG and e-LNG are among the most viable options to decarbonise shipping, if sufficient carbon pricing is put in place.

- Bio-LNG is competitive in terms of costs and GHG emissions savings when compared to other potential alternatives such as biomethanol and electrofuels like e-ammonia, e-methanol and e-LNG.
- Bio-LNG from anaerobic digestion of waste biomass represents an attractive choice for shipowners as:
  - The fuel cost is lower compared with other alternative fuels
  - The on-board energy conversion technology is mature and well-understood, with existing guidelines and established practices
  - There is an existing and developing infrastructure for transport and bunkering
  - A small but rapidly growing fleet of vessels is already running on fossil LNG, representing an existing asset base for the adoption of bio-LNG, especially as drop-in fuel.
- As e-LNG appears to have similar cost and emission performance to other electrofuels it could gradually replace bio-LNG in the long term as the demand for alternative low carbon fuels grows and the price of hydrogen decreases.

The adoption of bio-LNG in shipping will be linked to the widespread use of biomethane across other sectors.

- The large-scale development and usage of biomethane and bio-LNG for the shipping industry and other sectors will require regulation in two key areas:
  - First, national and international standards for biomethane injection into gas grids.
  - Second, a commonly accepted, and preferably legally binding, certificate of origin scheme to facilitate efficient trading in biomethane in its gaseous and liquefied forms and reduce transportation costs

Bio-LNG is a robust alternative fuel solution for the decarbonisation of the shipping sector thanks to:

- Significant global supply potential as a marine fuel
- Competitive cost compared to other sustainable biofuels and electrofuels
- Mature and commercially available technologies for fuel production and use on-board ships
- Existing and developing infrastructure for transportation and bunkering of LNG.

SEA–LNG

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