Emission reduction by biogas use in short sea shipping

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1. Introduction

Climate change recently has received increased attention in the shipping sector. This is mainly due to growing awareness of the need to cut global emissions and the fact that shipping is one of the fastest-growing sectors in terms of greenhouse gas (GHG) emissions [1]. In April 2018 IMO'S Marine Environment Protection committee (MEPC) finalized and adopted the Initial IMO Strategy on Reduction of GHG Emissions from Ships, designed to minimise air pollution in line with the central climate goal defined in the Paris Agreement, limiting global warming to well below 2°C. More specifically, MEPC outlined a target to reduce the total annual GHG emissions by at least 50 % by 2050 compared to 2008, while also pursuing efforts to phase them out completely [2].

The shipping industry is now striving to find strategies to meet forthcoming emission regulations. Fuel is an important factor in emissions, so a transition to alternative fuels is one of the options being examined. However, a fuel's environmental impact relates not only to combustion in the engine but also to its whole life-cycle, starting at the well [3]. Fuels invariably incur release of emissions at various stages of their life-cycle, such as during refining and transport [4]. This means that use of a fuel that appears favourable in the combustion phase may have large environmental impacts in the upstream processes or vice versa [3]. Considering the environmental life-cycle impacts of fuels is therefore essential to ensure any alternative fuel delivers meaningful emissions savings. [4]

There is increasing focus on gas as an alternative to conventional fuels. Switching to LNG instead of heavy fuel oil would significantly improve the overall environmental performance because gas produces less NO_x and particulates in the exhaust, and SO_x emissions are almost eliminated. However, the impact on climate change is less clear. In contrast, liquefied biomethane (LBG) exhibits, in principle, a neutral recirculation loop for CO_2, which is one of the main causes of global warming.

Reducing the impact on climate change is important for all shipping segments, but for short sea vessels in regional operations near coasts and populated areas, local pollutants must also be addressed [5]. In this study, the emission performance of LBG in short sea shipping was investigated and compared to LNG and conventional marine diesel oil (MDO). The emissions quantified are three greenhouse gases (CO_2, CH_4, and N_2O) and four local pollutants (SO_x, NO_x, NH_3, and particulate matter). Life Cycle Assessment (LCA) was used to assess the complete global warming potential of each fuel. The local and regional environmental impacts of their combustion were also assessed. The study used a Ro-Ro/passenger ship vessel scheduled service in the Baltic Sea ECA as its basis.

2. Materials and methods

Table 1. Modelling choices of the study.

Functional unit	1 year of RoPax ferry service to and from Vaasa and Umeå
Fuel chains	Marine Diesel Oil (MDO) 0.1 % S Liquefied natural gas (LNG) Liquefied biomethane (LBG)
Geographical boundaries	The sulphur emission control area (SECA) in the Baltic Sea The NO_x emission control area (NECA) in the Baltic Sea (1.1.2021)
System boundary	For GHG-emissions, the whole fuel life cycle is included from raw material extraction to combustion in marine engines. Local and regional environmental impacts are assessed from the tank-to-propeller perspective.
Included primary pollutants	GHG (LCA) • carbon dioxide (CO_2), • methane (CH_4), • nitrous oxide (N_2O) Other pollutants (local and regional impacts) • nitrogen oxides (NO_x), • sulphur dioxide (SO_2), • particulate matter (PM_{10}) and • ammonia (NH_3)
Impact categories	Global warming potential (GWP_{100}) Local and regional environmental impacts • Acidification potential • Eutrophication potential • Human health damage (DALY)

3. Results and discussion

All three investigated alternatives, LNG, LBG, and MDO combined with SCR, comply with the strictest ECA regulations currently in force or effective from 2021. However, the two gaseous fuels, LNG and LBG, showed better local and regional environmental performance compared to MDO+SCR in terms of their acidification and eutrophication potentials. Gaseous fuels also can deliver significant cuts to emissions of PM, yielding benefits in terms of impact on human health (Fig. 1).

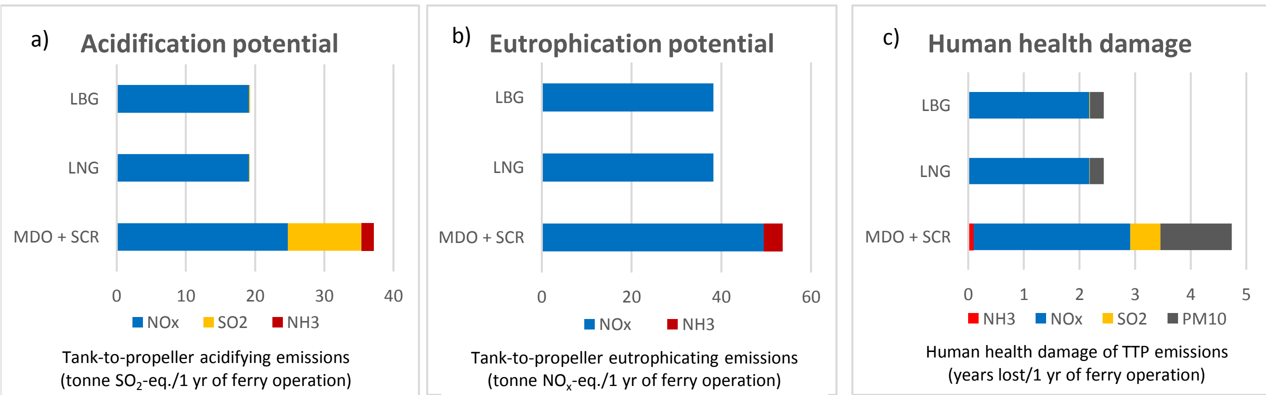

Figure 1. Environmental impacts with MDO, LNG and LBG for impact categories a) acidification potential, b) eutrophication potential, and c) human health damage.

This study identifies substantial life cycle GHG emission benefits associated with shifting from fossil fuels to LBG (Fig. 2). The CO_2-eq. reduction compared to LNG is evaluated at 58 %, and at 60 % compared to MDO. This difference stems from the fact that CO_2 emissions released when biomethane produced from organic waste materials is combusted are biogenic, making no contribution to climate change and so reported as zero. LBG's tank-to-propeller phase GHG emissions are mainly caused by methane slip from the dual-fuel engine and to a minor extent from the MDO pilot fuel used for ignition.

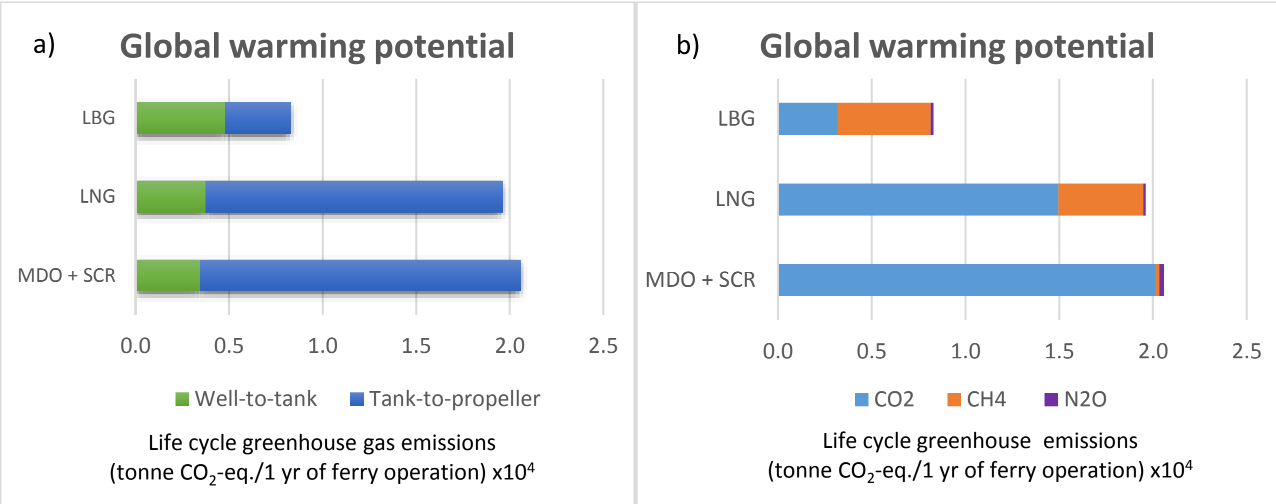

Figure 2. a) GWP_{100} for LBG, LNG and MDO+SCR divided into well-to-tank and tank-to-propeller phases. b) Life cycle GHGs divided into the different contributing emissions.

The overall GHG impacts of LNG are highly dependent on methane leakage rates in LNG production and distribution, and especially on methane slip rates from fuel combustion (Fig. 3). Approximately 2.5 % methane slip from fuel combustion cancels out the decreased emissions of CO_2, leading to GWP_{100} equal to diesel fuel's. Therefore, it seems LNG currently does not offer the significant CO_2-equivalent reduction needed to sustain the IMO's vision of decarbonising shipping. This conclusion is in line with many other studies [3, 4, 6, 7, 8].

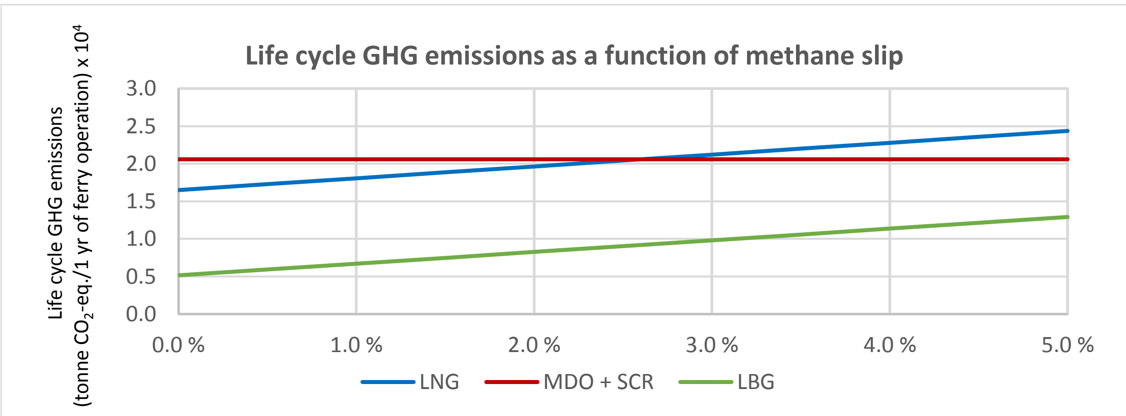

Figure 3. Life cycle GHG emissions as a function of methane slip from engine.

This study indicates the short sea shipping fuel with the best overall environmental impact is LBG, followed by LNG. LBG's lower life cycle emissions of greenhouse gases put it ahead of LNG. The major challenge for LBG is fuel availability in the quantities needed for shipping. Today, a switch to

LNG could be part of a long-term solution for short sea shipping, providing a bridge technology to be followed by the use of LBG. Introduction of biofuels on the market is also possible through blending with fossil fuels [1].

4. Conclusion

The purpose of this study was to evaluate the emissions performance of biogas in short sea shipping. Other investigated fuels were LNG, and MDO combined with SCR. Based on the life cycle GHG emission analysis and the emissions matrix for local air pollutants, the following conclusions could be made:

- LNG is a promising option for meeting existing regulation, but is not a low-GHG fuel.
- A shift to LNG in the shipping sector would have significant benefits in terms of reducing local air pollutants, but LNG's impact on climate change is of the same magnitude as that of traditional marine fuel.
- Reducing total annual emissions from shipping in line with the initial IMO strategy objective of at least 50 % GHG reduction by 2050 from 2008 levels seems possible only with fuel produced from renewable sources.
- The use of LBG produced from municipal organic waste has potential to reduce life cycle GHG emissions from short sea shipping by 60–75 % compared to marine diesel, and would also significantly reduce the impact of ship emissions on local air quality.
- The major challenge for LBG is fuel availability in the quantities needed for shipping.
- LNG can provide a bridge technology for a low-carbon shipping sector.
- Lowering methane emissions is an important development focus for the coming decade.

References

[1] Winnes, H., L. Styhre & E. Fridell (2015). Reducing GHG emissions from ships in port areas. *Research in Transportation Business & Management* 17, 73–82.

[2] IMO (2018). International Maritime Organization, Marine Environment Protection Committee, MEPC 72/17/Add.1, Annex 11, Resolution MEPC.304(72). Adopted on 13 April 2018. Initial IMO strategy on reduction of GHG emissions from ships.

[3] Bengtsson, S., K. Andersson & E. Fridell (2011). A comparative life cycle assessment of marine fuels: liquefied natural gas and three other fossil fuels. *Proceedings of the Institution of Mechanical Engineers, part M: Journal of Engineering for the Maritime Environment* 225, 97–110.

[4] Gilbert, P, C. Walsh, M.Traut, U.Kesieme, K. Pazouki & A. Murphy (2018). Assessment of full life-cycle air emissions of alternative shipping fuels. *Journal of Cleaner Production* 172, 855–866.

[5] Bengtsson, S., E. Fridell & K. Andersson (2013). Fuels for short sea shipping: A comparative assessment with focus on environmental impact. *Proceedings of the Institution of Mechanical Engineers, part M: Journal of Engineering for the Maritime Environment* 0(0), 1–11.

[6] Baresic, D., T. Smith, K. Raucci, C. Rehmatulla, N. Narula & I. Rojon (2018). LNG as a marine fuel in the EU: Market, bunkering infrastructure investments and risks in the context of GHG reductions. UMAS, London.

[7] Brynolf, S., M. Magnusson, E. Fridell & K. Andersson (2014b). Compliance possibilities for the future ECA regulations through the use of abatement technologies or change of fuels. *Transportation Research Part D* 28, 6–18.

[8] Verbeek, R. & M. Verbeek (2015). LNG for trucks and ships: fact analysis. Review of pollutant and GHG emissions. TNO Report R11668.