Work Group #4: Sustainable Marine Fuels

Deliverable 3.1 Report Review Template

1. Report title	**Life Cycle GHG Emission Study on the Use of LNG as Marine Fuel: Executive Summary**
2. Publication date	10-04-2019
3. Author	thinkstep AG
4. Client (organization and type of organization, specifying private/commercial/public; research institute/interest group etc.)	SEA\LNG Ltd and Society for Gas as a Marine Fuel Limited (SGMF) SEA\LNG Ltd is a 'multi-sector industry coalition whose members work together to demonstrate the benefits of LNG as a marine fuel throughout the entire value chain'. SGMF 'is an NGO established to promote safety and industry best practice in the use of gas as a marine fuel'.
5. Context of study (e.g. project in the context of which report is published or titles of other reports if part of a series)	Executive summary of the according final report
6. Length (pages)	11
7. Link (or where to get if not available online)	https://sustainableworldports.org/wp-content/uploads/thinkstep_2019_Life-cycle-GHG-emission-study-on-LNG-Executive-summary-report.pdf
8. Sector coverage	Maritime shipping
9. Main aim of the study	This document is the executive summary of a study which analyses the life cycle greenhouse gas (GHG) emissions of the use of Liquefied Natural Gas (LNG) as marine fuel compared with current and post-2020 conventional oil-based fuels. Based on this, the

	global warming potential of these fuels is assessed. In addition, air quality is assessed by comparing local pollutants from the operation of the vessels using these different fuels.
10. Methodology	Life cycle analysis, data collection from companies from the marine fuel and shipping sector.
11. Topic(s) and indication of the level of detail For example: • System Description - *A description of the full marine energy system.* • System Components - *A description of all the components.* • Infrastructure requirements for new fuels • Applicability - *which of the new fuels are expected to replace existing fuels?*	This executive summary includes the following paragraphs: • Key Messages from the Study – *bullets list* • Context of the international shipping industry, LNG and emissions – *short description* • Study Objectives – *short description of objectives and considered fuels* • Approach and Methodology – *short description of analysis approach and scope* • Well-to-Wake Results – *short description and quantitative results* • Methane Emissions Contribution Analysis – *short description and quantitative results* • Well-to-Tank Results – *short description and quantitative results* • Air Quality and Local Pollutants – *short description*
12. What are the main conclusions from the report?	According to thinkstep • LNG provides a significant advantage in terms of improving air quality and is a viable solution to reduce GHG emissions from international shipping. • On an engine technology basis, the well-to-wake (WtW) GHG emission reduction for LNG-fuelled marine ship engines compared with HFO-fuelled engines are between 14% to 21% for 2-stroke slow speed engines, and between 7% to 15% for 4-stroke medium speed engines. For tank-to-wake (TtW) GHG emissions, the reduction benefits are between 18% to 28% for 2-stroke slow speed engines and between 12% to 22% for 4-stroke medium speed engines. • Local pollutants are reduced when using LNG compared with current conventional marine fuels: sulphur oxides (SO_X) to close to zero, nitrogen oxides (NO_x) by up to 95% when using Otto cycle engines, and particulate matter (PM) by up to 99%.

	• If the global marine transport fleet for 2015 were to completely switch to LNG then there would be a reduction of 15% marine GHG emissions based upon engine technology alone. Methane emissions from the supply chain and engine slip need to be reduced further to maximise the positive impact on both air quality and GHG emissions. • BioLNG and synthetic LNG can provide a significant additional benefit in terms of WtW GHG intensity (up to 90%).
13. What fuel/energy type(s) are discussed in the report and in what level of detail? For example: • Fuel description e.g. type, energy density, specific energy density, flash point, boiling point, fire point, flammability limits, hazards	The amount of information is limited, but detailed numbers are given for some fuels. Mentioned fuels and figures are: • LNG – *GHG and local pollutants emissions reduction, fuel consumption, methane slip, CO2-eq. emission factor* • Heavy fuel oil (HFO) – *fuel consumption, CO2-eq. emission factor, methane emission factor* • Marine gas oil (MGO) – *fuel consumption, CO2-eq. emission factor, methane emission factor* • BioLNG – *only mentioned (no figures)* • Synthetic LNG – *only mentioned (no figures)* • Low sulphur fuel oil (LSFO) – *only mentioned (no figures)* • Liquefied petroleum gas (LPG) – *only mentioned (no figures)* • Methanol – *only mentioned (no figures)* For the oil-based fuels it is specified whether the fuel is a distillate fuel or a residual fuel.
14. What environmental aspects does the report consider? E.g. Air quality emissions, climate change emissions (GHG + BC), other (for example terrestrial or underwater noise, water quality, emergency releases, fugitive emissions, odour, water resources, mining)	GHG emissions, air pollutant emissions.
15. Does the report consider exhaust emissions only, or life-cycle, or both (or some other range of emissions)?	Both GHG emissions from the supply chain as well as released onboard ships (including methane slip) have been considered.

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<td>16. If determined in the report, what are the emission rates/factors by pollutant? NOx, SOx, PM10, PM2.5, ultra fine PM, VOC, NH3, GHGs, Black carbon, and any others e.g. that may be unique to the fuel/energy.</td>
<td>
CO_2-eq. emission factor (g CO_2-eq/kWh engine output):
<table>
<tr><th>Fuel</th><th>Engine</th><th>Well-to-tank</th><th>Tank-to-wake</th><th>Total</th></tr>
<tr><td>HFO</td><td>2-stroke slow speed diesel</td><td>114</td><td>583</td><td>697</td></tr>
<tr><td></td><td>4-stroke medium speed diesel</td><td>118</td><td>623</td><td>741</td></tr>
<tr><td>MGO</td><td>2-stroke slow speed diesel</td><td>121</td><td>565</td><td>686</td></tr>
<tr><td></td><td>4-stroke medium speed diesel</td><td>124</td><td>600</td><td>724</td></tr>
<tr><td>LNG</td><td>2-stroke slow speed diesel dual fuel</td><td>132</td><td>417</td><td>549</td></tr>
<tr><td></td><td>4-stroke medium speed Otto dual fuel</td><td>144</td><td>549</td><td>692</td></tr>
<tr><td></td><td>2-stroke slow speed Otto dual fuel</td><td>133</td><td>465</td><td>598</td></tr>
<tr><td></td><td>4-stroke medium speed Otto single fuel</td><td>141</td><td>488</td><td>629</td></tr>
</table>
CO_2-eq. emission factor (g CO_2-eq/MJ (LHV)):
<table>
<tr><th>Fuel</th><th>Well-to-tank</th></tr>
<tr><td>LNG</td><td>18.5</td></tr>
<tr><td>Oil-based fuels</td><td>13.2-14.4</td></tr>
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<tr>
<td>17. Does the report discuss barriers and opportunities for ships to use the fuel(s)/energy? Does the report identify the maturity level of the fuel on a regional or global scale with respect to use by vessels?</td>
<td>No (to both questions).</td>
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<tr>
<td>18. Does the report discuss barriers and opportunities for ports to provide the fuel(s)/energy? Does the report identify the</td>
<td>No (to both questions).</td>
</tr>
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maturity level of the fuel on a regional or global scale with respect to provision by ports?	
19. Does the report include capital and operating cost estimates for the ship and/or land-side?	No.
20. When are the fuel(s)/energy expected to be at a demonstration stage vs. commercialization? For example: • Technology Readiness Level of the system - *Estimated maturity of the system technology* • On Board Safety Readiness Level of the system - *Estimated maturity of the risk mitigations on board (on a scale of 1-9)* • External Safety Readiness Level of the system - *Estimated maturity of the risk mitigations for bunker operations (on a scale of 1-9)*	This is not discussed.
21. Are the fuels suitable for short and/or long (trans-oceanic) voyages?	This is not explicitly discussed.
1. Does the report identify/discuss potential issues around community acceptance for this fuel, or potential social/community impacts associated with the system?	This is not discussed.