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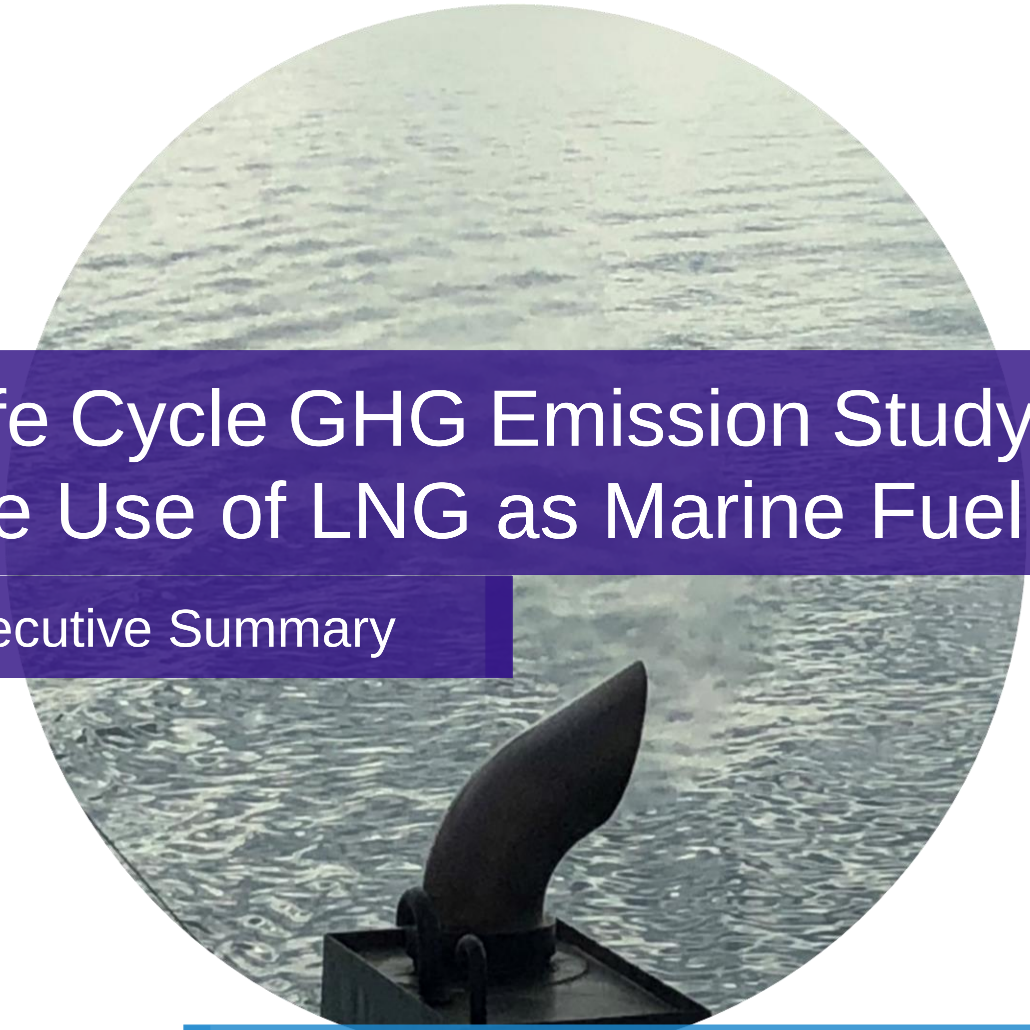

Life Cycle GHG Emission Study on the Use of LNG as Marine Fuel

Executive Summary

On behalf of SEA\LNG and SGMF

thinkstep

Client:	**SEA\LNG Limited, and Society for Gas as a Marine Fuel Limited (SGMF)**
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On behalf of thinkstep AG and its subsidiaries

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Executive Summary

This study analyses the life cycle greenhouse gas (GHG) emissions of the use of Liquified Natural Gas (LNG) as marine fuel compared with current and post-2020 conventional oil-based fuels. In addition, air quality is assessed by comparing local pollutants from the operation of the vessels using these different fuels.

Key Messages from the Study

The collaboration and support from a large number of SEA\LNG and SGMF member companies working across the entire fuel supply chain and engine manufacturers enabled the collection of up-to-date, quality technical data. This has provided the basis for a complete and accurate life cycle analysis of the GHG intensity expressed in terms of CO_2-equivalents. For the main GHG emissions, the IPCC AR5 characterisation factors have been used (1 CO_2, 30 CH_4, 265 N_2O) to assess the global warming potential (GWP_{100}). Methane emissions from the supply chains as well as methane released at the ship combustion process (methane slip) have been carefully included. The comparison between LNG and oil-based fuelled engines is performed on a 1 kWh brake power specific unit (g CO_2-eq/kWh).

The study shows that LNG provides a significant advantage in terms of improving air quality which is particularly important in ports and coastal areas. Beyond the benefits associated with reducing air pollutants, LNG is a viable solution to reduce GHG emissions from international shipping and to contribute to the International Maritime Organization (IMO) GHG reduction targets. However, methane emission from the supply chain and engine slip need to be reduced further to maximise the positive impact on both air quality and GHG emissions.

The key messages are:

- The use of LNG as marine fuel shows GHG reduction of up to 21 % compared with current oil-based marine fuels over the entire life cycle from Well-to-Wake (WtW). The benefit is highly dependent on the engine technology installed and, to a certain extent, on the type of reference fuel (distillate or residual).
- On an engine technology basis, the WtW GHG emission reduction for gas fuelled 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.
- On a Tank-to-Wake (TtW) basis, the combustion process for LNG as a marine fuel shows GHG benefits of up to 28 % compared with current oil-based marine fuels. On an engine technology basis, the TtW emissions reduction benefits for gas fuelled engines compared with HFO fuelled engines are between 18 to 28 % for 2-stroke slow speed engines and between 12 to 22 % for 4-stroke medium speed engines.
- Local pollutants, such as sulphur oxides (SO_X), nitrogen oxides (NO_X) and particulate matter (PM), are reduced when using LNG compared with current conventional marine fuels. Due to the negligible amount of sulphur in the LNG fuel, SO_X emissions are reduced close to zero. NO_X emissions are reduced by up to 95 % to meet the IMO Tier III limits without NOx reduction technologies when using Otto cycle engines. Limited data on PM emissions is available, however reductions of up to 99 % are normal compared with heavy fuel oil (HFO).
- For post-2020 oil-based marine fuels (low sulphur fuel oil (LSFO) or the use of HFO in combination with an exhaust gas cleaning system) there is no significant difference in the WtW GHG emissions compared with current oil-based fuels. Post-2020 gas fuelled 2-stroke

engines have advantages in the order of 14 % to 22 % (current: 14-21 %), and 4-stroke engines between 6 % to 16 % (current: 7-15 %) compared with HFO fuelled engines.

- As a direct comparison if the global marine transport fleet for 2015 were to completely switch to LNG then there would be a GHG emission reduction of 15 % marine GHG emissions based upon engine technology alone.
- GHG reductions are reduced depending upon the degree of methane slip incurred during the combustion process. High pressure 2-stroke Diesel cycle engines and marine gas turbine propulsion units incur methane slip less than 1 % of the overall WtW GHG emissions. Low pressure 2-stroke and 4-stroke Otto cycle reciprocating engines are sensitive to methane slip with 10-17 % of the WtW GHG emissions resulting from unburned methane in the combustion process.
- This study presents the current status of the industry; ongoing optimisation in supply chain and engine technology developments will further enhance the benefits of LNG as a marine fuel. Methane slip reduction at combustion in the engines and methane emission reduction in the supply chain as well as further improving energy efficiency in combination with other measures such as enhanced operational methods and speed optimisation will make a major contribution to meeting the IMO's GHG emissions reduction target 2050 for shipping.
- An indicative analysis showed that bioLNG and synthetic LNG can provide an additional significant (up to 90 %) benefit in terms of WtW GHG intensity. Bio and synthetic LNG are completely fungible with LNG derived from fossil feedstocks. For example, a blend of 20 % bioLNG as a drop-in fuel can reduce GHG emissions by a further 13 % compared with 100% fossil fuel LNG.
- GHG emissions of fuel supply chains differ from region to region due to a large number of variables. Therefore, specific supply chain analyses as applied in this study have been key in order to get to a global average GHG intensity.

Context

The international shipping industry, as other industry sectors, are under pressure to reduce emissions. The International Maritime Organization (IMO) has announced the ambition to reduce the GHG emissions from international shipping by at least 50% by 2050 compared with 2008. More stringent air quality regulations, such as the IMO 2020 global sulphur cap, are also approaching.

In the light of the IMO 2020 global sulphur cap, conventional oil-based residual marine fuels will need to either change in their specification or be replaced by alternative fuels like LNG.

While the environmental benefits of LNG as the most promising alternative marine fuel are clear in relation to local pollutants such as sulphur oxides (SO_X), nitrogen oxide (NO_X), and particulate matter (PM), various studies have demonstrated different GHG impacts from the use of LNG. These differences have resulted from the studies using different assumptions, methodologies and data. Most important, the studies have used different data and assumptions about methane emissions in the LNG supply chain, and methane slip in ship engines. The end result is that there are divergent opinions about the GHG benefits of LNG as marine fuel which in turn influence views on whether LNG is a viable option to address GHG emissions.

Life cycle analysis of GHG emissions of LNG and oil-based marine fuels and their use is a complex topic due to different engine technologies in operation, the different fuels bunkered and their geographically specific supply chains. In addition, fuels and their supply chain GHG emissions may change over time, e.g. due to the introduction of the low sulphur standards.

The marine engine market, in contrast to the road transport market for instance, comprises of a multitude of different engine technologies for different shipping applications and power requirements. This results in the use of different engines with 2-/4-stroke, single/dual fuel, combustion cycle, efficiency, exhaust gas cleaning system, etc.. Hence, gas fuelled vessels cannot be summarised by one representative technology and propulsion and power provision system, and more differentiation is necessary when drawing further conclusions, particularly by ship type, size and operational parameters. Large container ships for instance, are used to transport goods from one continent to another, and hence mainly operate in deep-sea regions, mostly with a constant engine load after leaving the harbour. In contrast, ferries or cruise ships mainly operate in coastal areas, and may change engine load more frequently. For smaller ships such as support vessels and tug boats, engine response with many engine load changes is crucial. There is therefore not one single gas engine to be considered, but rather different engines with different performance, fuel consumption and emission characteristics.

For ocean-going shipping outside Emission Control Areas (ECAs), the fuel sulphur limit is currently 3.5 wt.%, changing to 0.5 wt.% from 2020 onwards. For shipping inside ECAs, the sulphur limit has been 0.1 wt.% since 2015. For NO_X emissions, different Tier limits (Tier I-III) apply based on the construction date of the ship and the engine speed. For engines build from 2016 onwards, Tier III limits apply inside Emission Control Areas (ECA). Outside these areas, Tier II limits apply.

Study Objectives

SEA\LNG and SGMF commissioned *thinkstep* to perform a comprehensive, industry-wide Well-to-Wake (WtW) GHG emission analysis on the use of LNG as marine fuel. The intention was to reduce the uncertainty regarding the GHG benefits of LNG as marine fuel as mentioned above. Special focus was given to methane emissions. The study also investigated air quality aspects. By collecting primary, state-of-the-art data and by the integration of an external critical review the main study objectives were achieved.

While the analysis has been performed on a global level, it considers:

- the most common ship engine technologies in operation, taking into account the specific fuel consumption and methane slip.
- a global average LNG supply inventory, based on ‘bottom-up’ calculations of different regional consumption mixes, and LNG production countries.
- a differentiated view on various oil-based marine fuels, taking into account different fuel types and specifications, as well as post-2020 sulphur limits (including exhaust gas cleaning systems). Different regional analyses have also been carried out, analogous to the LNG supply analysis.

In 2018, the most common marine fuels were oil-based Heavy Fuel Oil (HFO) with a global average sulphur content of 2.5 wt. % and Marine Gas Oil (MGO) with 0.1 wt. % sulphur, which is primarily used in ECAs. HFO made up more than 75 % of the marine fuels followed by MGO with around 20 %. As mentioned, the upcoming more stringent air quality regulations relating to SO_X and NO_X, will change the marine fuel portfolio.

Today, it is not known how refiners will provide marine fuel that will comply with the IMO 2020 sulphur regulations for global fuels with a maximum of 0.5 wt.% sulphur. Fuel makers are likely to treat the fuel to reduce the sulphur, or blend it with ultra-low sulphur fuel oil, e.g. blending hydro-treated residuals, heavy fractions from hydrocrackers and lighter hydro-treated fractions or blending it with low sulphur MGO. Other options to obtain a 0.5 wt. % sulphur content fuel include the usage of a low sulphur crude oil feedstock. There will be a wide variability of fuel oil quality depending on input crude, refining process, blend strategy, and region.

Based on the available information and considerations of likely future actions, the project consortium defined the following current and “post-2020” fuels for consideration in this study:

Current fuels considered:

- Liquefied Natural Gas (LNG)
- Marine Gas Oil (MGO) as distillate marine fuel with a sulphur content of 0.1 wt. %
- Heavy Fuel Oil (HFO) as residual marine fuel with an average sulphur content of 2.5 wt. % (global average)

Post 2020 fuels considered:

- Liquefied Natural Gas (LNG)
- Marine Gas Oil (MGO) as distillate marine fuel with a sulphur content of 0.1 wt. %
- Heavy Fuel Oil (HFO) as residual marine fuel with an average sulphur content of >2.5 wt. % with scrubbers as approved exhaust gas cleaning system (EGCS)
- Low Sulphur Fuel Oil ($LSFO_{0.5,\ LScrude}$) as residual marine fuel with a sulphur content of 0.5 wt. %, using low sulphur crude oil as feedstock in refineries
- Low Sulphur Fuel Oil ($LSFO_{0.5,\ Blend}$) as blend of residual and distillate marine fuels with a sulphur content of 0.5 wt. %.

Other alternative fuels, e.g. Liquified Petroleum Gas (LPG), methanol, bioLNG, and synthetic LNG are also analysed in this study.

Approach and Methodology

The analysis distinguishes between the following ship engines and their specific characteristics when operating on different fuels:

- 2-stroke slow speed dual fuel engines
- 4-stroke medium speed single and dual fuel engines
- 4-stroke high speed single fuel engines
- Gas turbines in simple and combined cycle.

These engine technologies are further distinguished by combustion cycle, i.e. Otto combustion cycle (low pressure gas injection) and diesel combustion cycle (high pressure gas injection). Steam turbines as a main fuel oil engine are not analysed in this context due to the small number of vessels in operation with this technology. However, within the LNG supply chain analysis, steam turbines are considered as engine technology in LNG carriers in this study.

The data collection in particular focussed on ship engine data provided by eight major engine manufacturers (OEMs) incorporating the latest engine technologies and performance attributes. Main data providers were Carnival, Caterpillar MaK, Caterpillar Solar Turbines, GE Aviation, MAN Energy Solutions, MTU Friedrichshafen, Winterthur Gas & Diesel and Wärtsilä. On the fuel supply chains, ExxonMobil, Shell and Total were engaged in this study.

The study details the complete Well-to-Wake GHG emissions analysis of the LNG supply and use as marine fuel. The results of this analysis are compared with the WtW GHG emissions of other marine fuels in order to show the advantages and disadvantages. The study also includes a summary indicative outlook looking at the integration of bioLNG and synthetic LNG into the LNG supply chain. In addition, scenarios of potential future developments and technical improvements are investigated such as more efficient technologies which would reduce methane emissions.

The study is based on steady-state test-bed data using standard test cycles. GHG emissions based on actual operational fuel consumption and measured emissions data will differ due to load cycles and duration and could be considered as further analysis. However, this is the case for both LNG and fuel oil engines.

This assessment considers global warming as an environmental impact category only. However, the study assesses the supply and use of LNG as a marine fuel according to ISO 14040/44 and compares the GHG results with values for other marine fuels.

Air quality related local pollutants of sulphur oxides (SO_X), nitrogen oxides (NO_X) and particulate matter (PM) of the fuel combustion are also presented in the results.

The focus of this study is on the data collection and calculation of the GHG emissions of ship engines for LNG and oil-based fuels. For both, primary data has been provided by the OEMs.

In general, the chosen approach regarding GHG emissions can be seen as conservative from a LNG perspective (i.e. not favouring LNG) compared with oil-based fuelled ships, because a) for oil-based engines black carbon emissions are not considered (though potentially contributing to the global warming potential), b) for oil-based fuelled engines low mark-up values for EGCS operation are used, c) GHG impacts occurring as a result of a chemical reaction of used EGCS cleaning water (at open loop EGCS) and sea water are neglected and d) it is assumed that up to 90 % of the measured total hydrocarbon tailpipe emissions of the LNG engine are pure methane (recent studies show lower numbers). The key findings are:

Well-to-Wake Results

As described above, the total WtW GHG emissions of marine engine are highly dependent on the engine technology and fuel type. The overall Well-to-Wake GHG emissions of the marine engines operating on current oil-based HFO, MGO and LNG have been calculated based on fuel consumption and emission data provided by eight different engine manufacturers and members from SEA\LNG and SGMF. All data is related to compliance with the IMO Tier III NO_X limits, and are given in brake power specific units (kWh) per engine technology weighted according to the IMO E2/E3 cycle. The following tables shows the technical parameters (all primary data are provided by engine manufacturers) that are used for the calculation of the Well-to-Wake GHG emissions of the 2-stroke slow speed and the 4-stroke medium speed engines. Please note that all energy related numbers in this study are referring to the lower heating value (LHV).

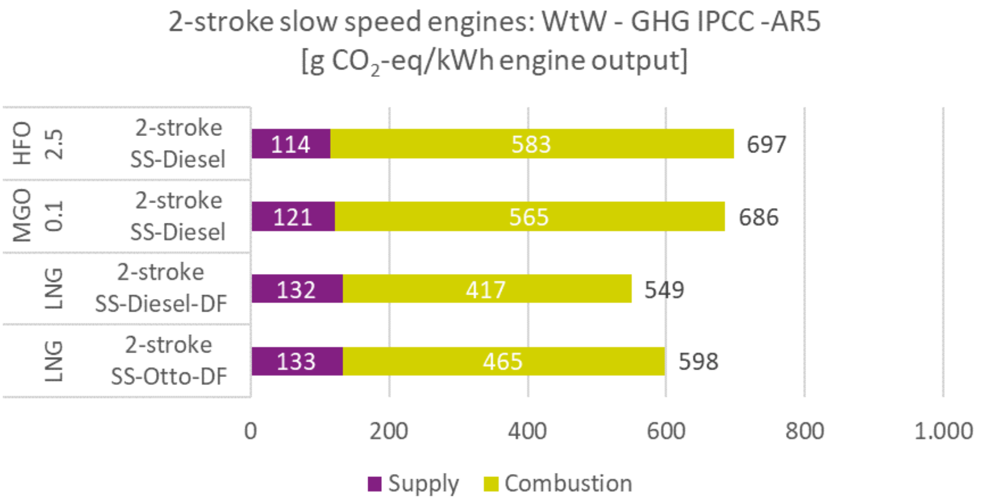
g/kWh	**Oil-based fuels**		**Gas-based fuel**	
	$HFO_{2.5}$	$MGO_{0.1}$	LNG	LNG
2-stroke slow speed	Diesel		Diesel-DF	Otto-DF
Main fuel consumption	184.8	174.0	141.3	145.1
Pilot fuel consumption	-	-	6.4	1.5
Urea solution consumption	20.7	20.7	-	-
Methane slip	-	-	*0.1 %*	*1.5 %*

g/kWh	**Oil-based fuels**		**Gas-based fuel**	
	$HFO_{2.5}$	$MGO_{0.1}$	LNG	LNG
4-stroke medium speed	Diesel		Otto-SI	Otto-DF
Main fuel consumption	197.5	184.7	155.8	156.5
Pilot fuel consumption	-	-	-	2.8
Urea solution consumption	15.7	15.7	-	-
Methane slip	-	-	*1.3 %*	*2.5 %*

2-stroke slow speed engines are the most common engines in shipping and burn more than 70 wt. % of the fuel used in the industry. Due to their high efficiency and high power, these engines are mainly used in large ocean-going cargo ships. LNG is used in two engine technologies which differ in their underlying combustion cycle and gas injection system.

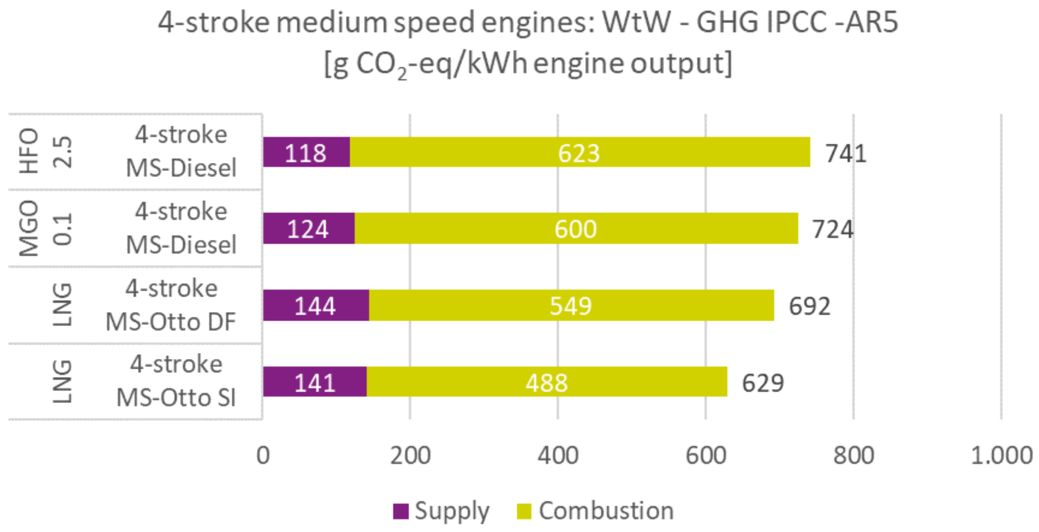
a) The WtW GHG emissions of the 2-stroke slow speed Diesel dual fuel engine (high pressure gas injection) are 549 g CO_2-eq/kWh when using LNG which is 21 % less compared with the same engine operating on HFO (697 g CO_2-eq/kWh) as shown in the figure below.
b) The WtW GHG emissions of the 2-stroke slow speed Otto dual fuel engine (low pressure gas injection) are 598 g CO_2-eq/kWh when using LNG which is a reduction of 14 % compared with HFO operation.

For these LNG fuelled engines, the WtT GHG emissions of the supply chain contribute about 22-24 % of the entire life cycle emissions (WtW). For oil-based fuels, the supply chain accounts for 16-18 %.



4-stroke medium speed engine are the second most common engine (18 wt. % of fuel burned) used in shipping. They typically have a lower engine power and are mainly used in car and passenger ferries as well as cruise ships. Both engines investigated in the study are Otto cycle engines and can be differentiated according to their ability to run on single (SI) or dual fuel (DF).

a) The WtW GHG emissions of the 4-stroke medium speed Otto-DF engine are 692 g CO_2-eq/kWh running on LNG which is a 7 % reduction compared with operation on HFO (741 g CO_2-eq/kWh).
b) The WtW GHG emissions of the 4-stroke medium speed Otto-SI engine which is a single fuel, pure gase engine, are 629 g CO_2-eq/kWh resulting in a 15 % reduction compared with HFO.



4-stroke high speed engines only account for 6 wt.% of the fuel burned in shipping, with gas turbines in simple and combined cycle operation having a minor share of 2 wt.%. Nonetheless, these engines are also analysed in the study and described in detail in the report. The high speed engines and gas turbines only run on $MGO_{0.1}$ and LNG. 4-stroke high speed engines show a potential GHG reduction of 5 % compared with $MGO_{0.1}$.

Gas turbines in simple and combined cyle have a methane slip during the combustion accounting for only 0.3 % of the overall WtW GHG emissions. Simple operation gas turbines using LNG give a benefit of 16 % compared with $MGO_{0.1}$, or 20 % in combined cycle operation.

The comparison of LNG fuelled engines with post-2020 oil-based fuelled engines shows similar GHG results as for the current situation, depending on the post-2020 fuel type and engine technology. For 2-stroke engines the advantages of gas fuelled engines are calculated to be 14-22 % (current fuels: 14-21 %) and for 4-stroke engines 6-16 % (current fuels: 7-15 %).The main reason for the high range of GHG reduction potential is the methane slip during the combustion phase which is mainly dependent on the combustion cycle of the engine and evaluated in more detail below.

Methane Emissions Contribution Analysis

Methane emissions can have a significant impact on the total WtW GHG emissions of marine engines. For oil-based marine fuels, methane emissions are limited to the supply chain of the fuel. In LNG operation, the methane slip in the engine (combustion) plays an important role in addition to the emission from the supply chain. The following tables show an analysis along the life cycle of the fuel and the contribution of supply and combustion. GHG emissions resulting from methane account for around 3 % of the total WtW GHG emissions of oil-based fuels ($HFO_{2.5}$ and $MGO_{0.1}$ in the following tables) and can be considered as insignificant whereas this goes up to 22 % for certain engines combusting LNG (to be considered as significant).

Methane emissions in the supply chain are mainly fugitive emissions. Methane emissions from the combustion of the fuel show a strong dependency from the combustion cycle.

Due to the high gas injection pressure and the combustion in a Diesel cycle, methane emission in the combustion of the 2-stroke slow speed Diesel-DF engine are about 4 g CO_2-eq/kWh representing less than 1 % of the total WtW GHG emissions. The data of the 2-stroke slow speed Otto cycle engine shows that methane slip accounts for 63 g CO_2-eq/kWh which is equal to 11 % of the total WtW GHG emissions.

g CO_2-eq/kWh	Oil-based fuels		Gas-based fuel	
	$HFO_{2.5}$	$MGO_{0.1}$	LNG	LNG
2-stroke slow speed	Diesel		Diesel-DF	Otto-DF
Total WtW GHG emissions	697	686	549	598
- of which methane	23	24	37	96
- supply	*23*	*24*	*33*	*33*
- combustion	-	-	*4*	*63*

The same characteristics apply for 4-stroke medium speed engines with the two engine technologies investigated using an Otto combustion cycle. The data indicates that pure gas engines (Otto-SI) are less sensitive to methane slip. It accounts for 10 % (60 g CO_2-eq/kWh) of the total WtW GHG emissions of the Otto-SI engine. The dual fuel engines covered in the study show GHG emissions resulting from methane slip of 115 g CO_2-eq/kWh which is equal to 17 % of the total WtW GHG emissions.

g CO_2-eq/kWh	Oil-based fuels		Gas-based fuel	
	$HFO_{2.5}$	$MGO_{0.1}$	LNG	LNG
4-stroke medium speed	Diesel		Otto-SI	Otto-DF
Total WtW GHG emissions	741	724	629	692
- of which methane	24	25	96	151
- supply	*24*	*25*	*36*	*36*
- combustion	-	-	*60*	*115*

Well-to-Tank Results

Focusing on the Well-to-Tank analysis, results from the study are as follows:

- The carbon footprint of the global LNG supply is calculated at 18.5 g CO_2-eq/MJ (LHV) from Well-to-Tank. The global LNG supply is based on the analysis of five LNG consuming regions (Europe, North America, Asia Pacific, China, and Middle East) which are based on the LNG supply chains of the nine most important and emerging LNG producing countries (Algeria, Australia, Indonesia, Malaysia, Nigeria, Norway, Qatar, Trinidad & Tobago and the USA), covering more than 72 % market share per region.
- Contributions to GHG emissions over the total life cycle are:
  - Gas production, processing and pipeline transport to the liquefication plant (33 % contribution, caused by energy consumption and methane emissions)
  - Gas liquefaction and purification (50 % contribution, caused by energy consumption)
  - LNG carrier transport (13 % contribution, defined by the distance travelled and the utilisation (in terms of time) of the LNG carrier)
  - LNG terminal operations and bunkering (4 % contribution, caused by energy consumption and methane emissions).
- For the LNG supply, carbon dioxide is the major GHG contribution at 74 %, followed by methane at 25 %. N_2O is negligible. The CO_2 emissions mainly come from fuel combustion, with small amounts of CO_2 vented during processing and purification of Natural Gas (CO_2-removal) if no carbon capture and storage is applied in the corresponding country. The main sources for the CH_4 emissions are fugitive emissions.
- The Well-to-Tank analyses of the current and post-2020 oil-based fuels are in the same order of magnitude, ranging from 13.2 to 14.4 g CO_2-eq/MJ (LHV) fuel. The calculation of the WtT GHG results of refinery products is associated with a range of uncertainties. Different crude

oil properties and refinery settings, different levels of desulphurisation and blending ratios, and assumptions made, as well as methodological differences such as different allocation methods can lead to different results. This means that interpretation of results and comparison between studies needs to be undertaken with care. However, the global supply of oil-based marine fuels has a lower WtT GHG intensity compared with LNG.

- For both, LNG and oil-based fuel supply chains, GHG emissions differ from region to region due to different natural reservoir characteristics, and hence production technologies applied, ambient temperatures at liquefaction (LNG supply only), transport distances, etc. Technology consideration as well as specific supply chain analyses to get to a global average are key for the assessment of the supply chains.

Air Quality and Local Pollutants

Although the focus of the study is on GHG emissions of the supply and use of LNG compared with other marine fuels, the influence of the fuel combustion on air quality is investigated but limited to the Tank-to-Wake stage of the life cycle. Sulphur oxide (SO_X), nitrogen oxide (NO_X) and particulate matter (PM) emission data were reported by the engine manufacturers for the operation with LNG, HFO and MGO. Based on these data, the following conclusions are drawn:

- Due to the absence of sulphur in LNG, sulphur oxide emissions of LNG are zero for pure gas engines, and negligible for dual fuel engines where a small amount of sulphur oxide emissions occur due to the use of pilot fuel. Oil-based pilot fuel is self-ignitable and is needed in dual fuel engines to function as a spark plug for the gas. Because it accounts for only 1 to 5 % of the fuel used in normal engine operation, LNG has a clear advantage compared with oil-based fuels.
- NO_X emissions are mainly dependent on the underlying combustion cycle. Most gas fuelled engines utilise the Otto cycle and comply with the strict IMO Tier III NO_X limits (e.g. for ECAs) without any NO_X after-treatment system. The 2-stroke slow speed Diesel-DF engines complies with Tier III by incorporating exhaust gas recirculation (EGR) or selective catalytic reduction (SCR) systems.
- PM measurement data was provided for gas turbines and 4-stroke medium speed engines. Based on these data, LNG can deliver a PM reduction of up to 99 % compared with oil-based marine fuels.

About us

- SEA\LNG is a UK-registered not for profit collaborative industry foundation serving the needs of its member organisations committed to furthering the use of LNG as an important, environmentally superior maritime fuel. www.sea-lng.org
- The Society for Gas as a Marine Fuel (SGMF) is a non-governmental organisation (NGO) established to promote safety and industry best practice in the use of gas as a marine fuel. www.sgmf.info
- thinkstep enables organizations worldwide to succeed sustainably. thinkstep's industry-leading environmental sustainability software, data and consulting services help businesses drive operational excellence, product innovation, brand value and regulatory compliance. www.thinkstep.com

The full study can be downloaded at: https://info.thinkstep.com/LNG-GHG-Study