marcogaz

LIQUEFIED NATURAL GAS AND HYDROGEN AS TRANSPORTATION FUEL

June 2021

Contact

MARCOGAZ AISBL

Rue Belliard, 40

1040 Brussels – Belgium

marcogaz@marcogaz.org

www.marcogaz.org

ABOUT MARCOGAZ

Founded in 1968, MARCOGAZ is the technical association of the European gas industry. It represents 30 member organisations from 20 countries. Its mission encompasses monitoring and policy advisory activities related to the European technical regulation, standardisation and certification with respect to safety and integrity of gas systems and equipment, rational use of energy as well as environment, health and safety issues. It is registered in Brussels under number BE0877 785 464.

DISCLAIMER

TABLE OF CONTENT

1. INTRODUCTION

Liquefied natural gas (LNG) is becoming an attractive alternative to traditional transportation fuels such as diesel and heavy fuel oil. The major advantages in terms of pollutant and noise emissions make it attractive for powering ships and on- and off-road vehicles. The drive towards sustainability and to reduce the CO_2 emissions even further have led to the increased interest of using (green) hydrogen and biogas as transportation fuel. However in this document we explore the blending of LNG with renewable fuels such as bio LNG for use as a fuel in marine applications, including its carbon mitigating potential, which is analysed to address maritime long term investments in the perspective of more stringent regulations on emissions. It is also presenting the implications of blending natural gas with (green) hydrogen.

Finally, new engine concepts are discussed that can help reducing the CO_2 emission and fuel consumption while maintaining optimum engine performance.

2. LNG + HYDROGEN

For transportation applications the LNG and the liquid hydrogen cannot be blended for physical reasons. At atmospheric pressure, LNG is liquid between -162°C and -182°C while, in this range of temperature, hydrogen is gaseous and cannot be blended since the mix of a liquid and a gas is not possible (biphasic).

<table>
<tr><th>Temperature</th><th>Natural gas</th><th>Hydrogen</th><th>Blending feasibility</th></tr>
<tr><td></td><td>Gaseous</td><td rowspan="5">Gaseous</td><td>Mix = possible
(but % of H_2 is limited[1])</td></tr>
<tr><td>-162°C</td><td></td><td></td></tr>
<tr><td></td><td>Liquid (LNG)</td><td>Mix impossible</td></tr>
<tr><td>-182°C</td><td></td><td></td></tr>
<tr><td></td><td rowspan="3">Solid</td><td>Mix impossible</td></tr>
<tr><td>-253°C</td><td></td><td></td></tr>
<tr><td></td><td>Liquid</td><td>Mix impossible</td></tr>
</table>

[1] Present, there is no engine that can switch from 100% LNG to 100% hydrogen. Other issues are currently investigated by MARCOGAZ.

3. LNG + RES LNG (bio LNG, synthetic LNG, …)

Despite the initial feedstocks are different, similar approach, as describe below, applies for each RES LNG.

At this moment, no physical (same range of temperature) and chemical limitation for blending LNG and RES LNG has been identified. However, the difference of quality needs to be addressed prior to the blending and the mix should comply with the standards:

- EN 16723-1 "*Natural gas and biomethane for use in transport and biomethane for injection in the natural gas network - Part 1: Specifications for biomethane for injection in the natural gas network*" specified the requirements for injection in the grids.
- EN 16723-2 "*Natural gas and biomethane for use in transport and biomethane for injection in the natural gas network - Part 2: Automotive fuels specification*" specifies automotive fuels application.
- For marine applications, EN ISO 23306 "*Specifications of Liquefied Natural Gas as a fuel for marine applications"* specifies the quality requirements for LNG used as a fuel for marine applications. The document identifies the components and physicochemical characteristics of the fuel that shall be measured or calculated and the related test methods. For example, the document provides information on the calculation of the methane number (PKI MN[2] and MWM[3]) and the Wobbe index.

4. CARBON MITIGATION POTENTIAL

European Commission's Joint Research Centre (EC-JRC) performed an evaluation "Well-to-Tank" (WTT study, v.5, 2020)[4] energy use and greenhouse gas (GHG) emissions. For the evaluation EC-JRC applied more than 250 modelled pathways, both in terms of WTT energy expended for production and resulting GHG emissions.

From the analysis of the results, the following general conclusions can be drawn regarding LNG and RES LNG:

- In terms of WTT energy required for fuel production, among fossil based fuels, the representative pathways for LNG and CNG resulted in more energy efficient routes than conventional crude oil based ones.
- Among the pathways with high-energy input, liquefied bio-methane (LBM) is included in the most WTT energy-intensive pathways.

---

[2] PKI MN is a tool to calculate Methane Number for LNG

[3] MWM is manufacturers calculation method of Methane Number for LNG

[4] https://ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/jec-well-tank-report-v5

- LBM/CBM (liquefied/compressed bio-methane) is among the pathways that offer the possibility to achieve negative WTT emissions. Biomethane negative emissions are results as a reduction of GHG emissions compared to a reference use (e.g. avoided CH_4 emissions) and this pathway is reducing emissions.

5. NEW ENGINE CONCEPTS

5.1. Example 1: Smart fuel-adaptive engine control system

The composition (the 'quality') of the LNG varies substantially with the geographical origin due to differences in natural gas sources, production technologies and target markets for the LNG. Confronted with this range of fuel compositions than normally specified for a given engine, manufacturers ordinarily must either derate the engine with the concomitant loss of performance or restrict the range of fuels. This may result in either a limitation of the supply options for the end user or increased processing cost for the fuel supplier, or in (structural) reduction in engine performance.

A better solution for both fuel suppliers and end users is the real-time adjustment of the engine settings based on the measured composition of the fuel that enters the engine. The advantage of such a feed-forward fuel-adaptive engine control system is that the engine only will be adjusted from its optimal setting (maximum power and efficiency) when the methane number is lower than specified.

Shell Global Solutions and DNV have tested a feed-forward fuel-adaptive control system, which combines a gas composition sensor located upstream of the engine and the DNV methane number algorithm to provide real-time engine performance optimization in response to changes in gas composition[5].

The results revealed substantial fuel savings (up to 6%) when demonstrating this concept on a lean-burn gas engine. Furthermore, a feed-forward fuel-adaptive control system maximizes the range of gas compositions for this market.

5.2. Example 2: LNG as a diesel fuel

With increased awareness and scrutiny of greenhouse gas (GHG) emissions, the heavy-duty truck industry is on the lookout for solutions that can maximize GHG savings, through either lowering fuel consumption and lowering methane slip[6].

Recently, high pressure direct injection (HPDI) truck engines using LNG have been successfully introduced into the market. The working principle of HPDI engines is the direct injection of the gaseous

---

[5] van Dijk, G., van Essen, M., and Gersen, S. (eds.), "A Feed-Forward Fuel-Adaptive Gas Engine Control Approach Based on a Knock-Prediction Algorithm," 17th Conference „The Working Process of the Internal Combustion Engine", Graz, Austria, September 26-27, 2019.

[6] Methane slip is gas that is not used as fuel in the engine and it escapes into the atmosphere during incomplete combustion escaping into the exhaust.

fuel (natural gas) in the cylinder during the high-pressure phase of the engine cycle. The start of the ignition of the injected gaseous fuel is triggered by the pre-injection of small amount (pilot) diesel fuel. The efficiencies obtained in HPDI engines are substantially higher and the use of HPDI results in lower CO_2 emissions and the methane slip is reduced substantially.

The removal of the diesel pilot injection would further improve the HPDI engine concept in term of the reduction of emissions (carbon dioxide (CO_2), methane (CH_4) and others), lower hardware cost (CAPEX) and lower operational cost (OPEX). However, the slow autoignition of most LNG compositions, responsible for its knock resistance, makes it unfit for (direct) use in diesel engines. To convert LNG into a diesel fuel, DNV and Shell Global Solutions investigated the option to enhance the autoignition of LNG by adding a cetane enhancing additive to LNG.

DNV and Shell Global Solutions recently successfully demonstrated a mono-fuel HPDI engine concept using a cetane enhanced LNG fuel (without the pre-injection of a diesel pilot)[7].

[7] Kofod, M., Sleeswijk Visser, F., Bosma, P., van Erp, M. et al., "LNG Fuel Differentiation: DME/LNG Blends for HPDI Engines," SAE Technical Paper 2020-01-2078, 2020, doi:10.4271/2020-01-2078.

6. LIST OF ACRONYMS

CBM	Compressed biomethane
DNV	Det Norske Veritas (company)
EC-JRC	European Commission's Joint Research Centre
GHG	Greenhouse Gas
HPDI	High Pressure Direct Injection
LBM	Liquified biomethane
LNG	Liquid Natural Gas
MN	Methane Number
RES	Renewable Energy Source(s)