COMPLIANT FUEL CHOICES
TODAY – Tomorrow?
1) Use of LNG as a Marine Fuel to comply with IMO 2020?

- HFO
- LSFO
- MGO/MDO
- MDO/MGO
- LNG
- LH2

2) Use of LNG as a Marine Fuel to comply with IMO 2050?

- LSFO
- MGO/MDO
- MDO/MGO
- LNG
- LH2
SGMF at a glance....

Membership Based NGO representing best practice for SAFE and SUSTAINABLE Gas fuelled shipping

- Formed in 2013 now with over 140 members across the sector
  - Including Suppliers / Owners / Operators / Class / OEMs / Shipyards / Port Authorities
  - (Open to all – not for profit)
- Provides Regulators with key guidelines as key input for National and International Standards
- Works with Industry at all Levels
  - IMO – EU – USCG – MPA and other NGOs
- Analyses and solves issues with regard to Safe Operations, Technical, Quality and Quantity, Training and Competence and Environmental matters
- Regular meetings and Forums across all Geographies for members interaction
- SGMF Portal is key resource for Industry data and member interaction www.sgmf.info
- IGF Code Vessel Focus
Who we work with......
Gas Fueled Value Chain
Regulatory Framework – SGMF Guidelines

- Gas as Fuel an introductory guide
- Bunkering Operational Guidelines
- Bunkering Competency Guidelines
- Quality & Quantity Contractual Guidelines
- Recommendations of Controlled Zone for LNG Bunkering
- Simultaneous Operations for LNG Bunkering
- Manifold Arrangements for IGF Vessels
- Quick Connect /Disconnect Couplings
- Safe Working Distances for LNG Bunkering
- ESD and Control systems
- LCA study for Gas Fuelled Shipping

Soon to come…

- Flexible Hose Selection and Handling
- Methane Number Considerations
- Dry Docking and Maintenance for IGF vessels
Gas Fuelled Fleet Progress 2019

- 170 LNG-fuelled ships in operation (0.2% of world fleet)
- 184 LNG-fuelled ships on order (0.4% of world fleet)
- 10 Vessels supplying LNG as fuel (180 m³ to 38,000 m³)
- 19 Vessels on order to supply LNG as fuel (Further 66,000 m³)
- 75 Ports/Terminals supplying LNG fuel (Estimate 9000+ LNG Bunker transfers so far)

Ref: DNV GL / SGMF members database 2019
<table>
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<tr>
<th>SHIP</th>
<th>Operator</th>
<th>IMO</th>
<th>Delivery</th>
<th>Cont</th>
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<td>Oizmendi</td>
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<td>Coral Methane</td>
<td>Anthony Veder</td>
<td>9404584</td>
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<tr>
<td>Clean Jacksonville</td>
<td>TOTE</td>
<td>\</td>
<td>2018</td>
<td>Membrane</td>
<td>2200</td>
<td>USA</td>
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<td>FlexFueler 1</td>
<td>Titan LNG</td>
<td>\</td>
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<td>Type C</td>
<td>1480</td>
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<tr>
<td>LNG London</td>
<td>Victrol / CFT</td>
<td>ENI 06105621</td>
<td>2019</td>
<td>Type C</td>
<td>3000</td>
<td>EU</td>
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| 10 In operation    |                   |              |          |      | 39,767        |        |
| 19 on order        |                   |              |          |      | +66,600        |        |
Life Cycle GHG Emission Study on the use of LNG as Marine Fuel

Final Results
Why this Study?

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 almost upon us.

Accurate, up-to-date and reliable GHG inventory data as well as local pollutant data are key to understand if LNG is a viable option to reduce GHG emissions and improve air quality in the international shipping industry.
Goal & Scope
Approach and Methodology

The analysis was performed:

- by following the life cycle approach (ISO 14040/44) from Well-to-Wake (WtW)
- for a global average fuel supply inventory, based on specific regional consumption mixes by specific production countries
- for current and post-2020 fuels
- for gas and oil-based ship engine technologies
- considering the most common ship engine technologies in operation, taken into account the specific fuel consumption and methane slip
- looking at GHG emissions and air quality
- using industry data, provided by

© thinkstep 2019
Well-to-Wake GHG Emissions
Critical Review

Following ISO 14040/44, this study is critical reviewed by independent experts.

Reviewers are:

<table>
<thead>
<tr>
<th>Reviewer</th>
<th>Organisation, Location, Position</th>
<th>Role</th>
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</table>
| Philippe Osset         | Solinnen, Paris (France)  
*CEO, member of the ISO 14040/14044 working group*                                             | Chair of Panel              |
| Prof. Dr. Atsushi Inaba | Kogakuin University (Japan)  
*Department of Environmental and Energy Chemistry*                                                | Reviewer                    |
| Prof. Dr. Friedrich Wirz| Hamburg University of Technology (Germany)  
*Head of Department Marine Engineering*                                                             | Reviewer                    |
| Dr. Michael Wang        | Argonne National Laboratory (USA)  
*Head of Systems’ Assessment Department*                                                            | Reviewer                    |
1. The use of LNG shows GHG reduction of **up to 21 %** compared with current oil-based marine fuels over the entire life cycle from Well-to-Wake (WtW).

2. On an engine technology basis, the WtW GHG emission reduction for gas fuelled engines compared with today’s HFO fueled engines are between **14-21 %** for 2-stroke slow speed engines, and between **7-15 %** for 4-stroke medium speed engines.

3. 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 fueled engines are between 18 to 28 % for 2-stroke slow speed engines and between 12 to 22 % for 4-stroke medium speed engines.

4. **Local pollutants**, such as sulphurous oxides, nitrogen oxides and particulate matter, are reduced significantly when using LNG.
6. Well-to-Wake GHG emissions (today’s fuels)

GHG reduction when using LNG: 14-21% compared with HFO$_{2.5}$
6. Well-to-Wake GHG emissions (today's fuels)

### 4-stroke medium speed engines: WtW - GHG IPCC-AR5

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Engine Type</th>
<th>CO₂-eq/kWh Engine Output</th>
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<tbody>
<tr>
<td>HFO 2.5</td>
<td>4-stroke MS-Diesel</td>
<td>118 + 623 = 741</td>
</tr>
<tr>
<td>MGO 0.1</td>
<td>4-stroke MS-Diesel</td>
<td>124 + 600 = 724</td>
</tr>
<tr>
<td>LNG</td>
<td>4-stroke MS-Otto DF</td>
<td>144 + 549 = 692</td>
</tr>
<tr>
<td>LNG</td>
<td>4-stroke MS-Otto SI</td>
<td>141 + 488 = 629</td>
</tr>
</tbody>
</table>

GHG reduction when using LNG: 7-15% compared with HFO₂.5
7. For post-2020 oil-based marine fuels (LSFO) or the use of HFO in combination with an exhaust gas cleaning system, the result is slightly better. LNG 2-stroke engines have GHG advantages between 14-22 %, and 4-stroke engines between 6-16 % compared with HFO fueled engines.

8. As a direct comparison if the global marine transport fleet\textsuperscript{2015} were to completely switch to LNG then there would be a GHG emission reduction of 15 % based upon engine technology alone.

9. GHG emission benefits 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 WiW GHG emissions.
   - Low pressure 2-stroke and 4-stroke Otto cycle reciprocating engines are more sensitive to methane slip with 10-17 % of the WiW GHG emissions resulting from unburned methane in the combustion process.
10. This study presents the current status of the industry; Ongoing optimisation in the fuel supply chain and engine technology developments will further enhance the benefits of LNG as a marine fuel.

11. An indicative analysis showed that bioLNG and synthetic LNG can provide an additional significant benefit in terms of WiW GHG intensity.

12. GHG emissions of fuel supply chains differ from region to region due to a large number of variables, specific supply chain analyses are key in order to get to a global average GHG intensity.
Emissions Fact Sheet

Gas as a Marine Fuel

LNG IS SAFE TO USE, FULLY COMPLIANT AND READY AVAILABLE AS A MARINE TRANSPORT FUEL.

LNG meets and exceeds all current and 2020 Marine fuel compliance requirements for content and emissions, local and global.

With the world LNG fleet doubling in the next 18 months and shore vessels being deployed at major bunkering hubs, LNG as a ship fuel is rapidly becoming readily available.

OBJECTIVE - Peer reviewed by leading academics from key institutions in Germany, Japan and USA.

QUALITY ASSURED - Assesses the supply and use of LNG as marine fuel according to relevant ISO standards.

COMPREHENSIVE - Uses latest primary data to assess all major types of marine engines and global sources of supply.

THIS REPORT IS THE DEFINITIVE STUDY INTO GHG EMISSIONS FROM CURRENT MARINE ENGINES.

LNG IS THE MOST ENVIRONMENTALLY-FRIENDLY FUEL FOR SHIPPING TODAY AND IN THE FORESEEABLE FUTURE.

LNG marine fuel GHG reduction Benefits:
- Well-to-Wake 21%
- Tank to Wake 28%

HFO+scrubber = LSFO WW emissions
But with LNG:
- 2 Stroke Gas engines 14% to 22% BOTHER
- 4 Stroke Gas engines 6% to 16% BOTHER

Methane slip can reduce GHG reduction benefits:
- HP 2 stroke Diesel 1% overall
- 2 & 4 stroke Otto 10% to 17%

If LNG fuelled the world fleet today it would emit 15% less GHG

Local pollutant reduction results with LNG
- SOx 100%
- NOx 95%
- PMs 99%

Whats next....
- Ship operation optimisation will further reduce emissions
- Use of \( L_{\text{inc}}G \) and \( L_{\text{syn}}G \) further reduce WW GHG emissions. Just a 20% blend can reduce it by further 13%

https://info.thinkstep.com/LNG-GHG-Study
Natural Gas as a Marine Fuel

- Safe to Use and becoming readily available
- Natural Gas [LNG] is a fully compliant IMO 2020 fuel
  GHG reduction: 21% wtw to 28% ttw
  Significant Local pollutant reduction: 100% SOx, 95% NOx, 99% PMs
- 15% CO2 reduction achieved if the world fleet switched today
- Distribution and supply is taking time and will continue to do so
- Marine Propulsion Engines can readily burn Methane
- Use of BioMethane and Synthetic methane would further improve wtw %
- Upstream CH4 losses can be reduced - improves wtt
  Further on board CH4 slip improvement is needed (4Stroke Gas engines)
Conclusions

• Alternative fuels are available – Natural Gas is one of them
• 2020 is already here and Gas is a Fully Compliant 2020 fuel

• 2050 trading ships are being built now
  Difficult to meet 2050 reductions without it’s extensive use
  Ship operational efficiency improvements will be key

• Currently 0.2% - Expect 2% (1500) - Won’t see 20% for a long time
  Deep sea sector – Cruise and Container showing large take – up of LNG

• 2020 – Another year of change for maritime fuels
we sea change, do you?

THANK YOU