Methanol: The bridging marine fuel
Dubai. Dec 11th 2018

Presented by: Captain Saleem Alavi
At Methanol as marine fuel seminar
Address Hotel, Dubai.
Dec. 11th 2018
Consulting assignments are client-specific, and conducted on a confidential basis. These assignments are diverse in nature but are typically undertaken to assist clients assess particular opportunities or to help develop strategic investment plans.

**Commercial consultancy** assignments have included the following:

- LNG Consultancy
- Corporate Strategy, KPI and balance scorecard
- Project Evaluation
- Fees Reviews
- Trade and Market Share Projections
- Market Research/Surveys
- Fleet Portfolio and sector Reviews
- Strategic Market Positioning
- Vessel Size and Route Evolution

Furthermore, we can mobilize additional expertise in the following areas:

- International Macroeconomic Forecasts
- Transportation Logistics
- Shipping and Project Financing

**Ship Owning and Management**:

- Gap Analysis
- KPI's
- Strategy
- HR Plan
- Fleet Utilization
- Ship Management Systems
- Procurement processes evaluation
- Fleet Portfolio Reviews
- Market Risk and Sensitivity Studies
- Drydock repair specifications
- Collision investigations
- Setting up of Ship Management division
- Crewing
- Crew competency evaluation
- Risk Analysis
Provided consulting services to a shipowner to set up in-house shipmanagement.

LNG offshore regasification terminal concept development.

Monetization of Offshore services off the coast of an East African country.

LNG Procurement strategy

Ship/LNG Terminal interface – regulatory requirements.

LNG Terminal revenue stream identification and projections.

Study on prospects of LNG as a bunkering fuel.

Study on alternate marine bunker fuels including well-to-propeller life cycle analysis.

Drafting of maritime regulations and laws (UAE)

Review of Fees structure of Maritime Administration (UAE)

Study on FSRU economics: FSRU new build vs conversion

Study on possibility of setting up of natural gas trading hub in UAE.

Study on Global shale gas and business opportunities.
GHG and Non-GHG Emissions: Ships

Under the GHG Protocol: six gases are categorized as greenhouse gases:
- carbon dioxide (CO2),
- methane (CH4),
- nitrous oxide (N2O),
- hydrofluorocarbons (HFCs),
- perfluorooctane sulphonate (PFCs),
- and sulphur hexafluoride (SF6).

Non-GHG Emissions In addition to GHGs, shipping produces other air emissions, most notably:
- sulphur oxides (SOx),
- nitrogen oxides (NOx)
- particulate matter (PM).

<table>
<thead>
<tr>
<th>GHG</th>
<th>Carbon Dioxide (CO2)</th>
<th>Methane (CH4)</th>
<th>Nitrous Oxide (N2O)</th>
</tr>
</thead>
<tbody>
<tr>
<td>gWP</td>
<td>20 years (kg CO2 eq/kg)</td>
<td>100 years (kg CO2 eq/kg)</td>
<td>500 years (kg CO2 eq/kg)</td>
</tr>
<tr>
<td>CO2</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>CH4</td>
<td>85</td>
<td>25</td>
<td>7.6</td>
</tr>
<tr>
<td>N2O</td>
<td>298</td>
<td>289</td>
<td>153</td>
</tr>
</tbody>
</table>

Global warming potential for different time horizons expressed relative to CO2 (IPCC, 2014)

NMVOC = Non-methane volatile organic compounds, such as benzene, ethanol, formaldehyde etc
CO = carbon monoxide gas produced by incomplete combustion of fossil fuels (coal, natural gas petroleum)
IMO’s Future Greenhouse Gas Regulations

IMO’s initial GHG strategy was adopted at its MEPC 72 meeting in April 2018 and would limit total GHG emissions in 2050 to 50% of actual GHG emissions in 2008. Additionally, IMO aims to have future GHG regulations defined and adopted by 2023. Shipowners are reluctant to invest in stack gas scrubbers if traditional marine fuels will have to be phased out over the next few years in favor of suitable alternate fuel that will address the forthcoming sulfur deadline as well as have the potential to address upcoming GHG related regulations.
Shipping industry at a glance (>1,000 gt) – still a roller coaster ride

Total world fleet stands at **94,585** vessels plus and orderbook of **3530** vessels.

<table>
<thead>
<tr>
<th>Type of Vessel</th>
<th>Average Demolition age (yrs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bulkers</td>
<td>25.9</td>
</tr>
<tr>
<td>Tankers</td>
<td>27.4</td>
</tr>
<tr>
<td>Gas ships</td>
<td>28.7</td>
</tr>
<tr>
<td>General cargo</td>
<td>27.8</td>
</tr>
<tr>
<td>Container</td>
<td>22</td>
</tr>
<tr>
<td>Passenger</td>
<td>35.7</td>
</tr>
</tbody>
</table>
Bunkers: Summary of annual bunker consumption and by ship type

Container vessels by far the largest consumer of marine fuels followed by oil tankers, bulk carriers, liquefied gas tankers and cruise ships.

In domestic shipping fishing vessels are followed by Ferry-Ropax and offshore
Factors that the ship owners need to consider in order to decide on technology selection

- Investment Costs
- Fuel price
- Operational Costs
- Safety & safe handling
- Security
- Public opinion
- Political and strategy aspects

FUTURE MARINE FUELS

Economic Criteria

Environmental Criteria
- Life cycle environmental performance
- Exhaust emissions
- Consequences of fuel spills and accidents

Technical criteria
- Fuel properties
- Propulsion system
- Fuel pre-treatment requirements
- Compliance criteria

Other Criteria
These fuels are:

1. Liquefied Natural Gas (LNG)
2. Liquefied Petroleum Gas (LPG)
3. Methanol and Ethanol
4. Di-Methyl Ether (DME)
5. Synthetic Fuels (Fischer-Tropsch)
6. Biodiesel
7. Biogas
8. Use of electricity for charging batteries and cold ironing
9. Hydrogen
10. Nuclear Fuel
Hydrotreater. Also known as: hydodesulfurization, HTU, HDS unit. The purpose of a hydrotreater unit is primarily to remove sulfur and other contaminants from intermediate streams before blending into a finished refined product or before being fed into another refinery process unit.
Estimated fuel demand due to MARPOL (MMb/d)

Maximum Impact [75% MGO Share]
- If ~ 90% compliance, is achieved primarily through MGO use:
- Can add up to 3.8MMb/d of crude to global oil demand by 2021.
- 75% MGO share is the best highest possible under current refinery configurations.
- Full refinery utilization is highly unlikely.
- Fuel switch will allow use of LSFO pushing MGO share down.

Under Investment [55% MGO Share]
- ~90% compliance is more likely to be achieved through a more equal split between MGO and low sulfur fuel oil, adding about 1.8MMb/d of demand by 2021.

Lower for longer {40% MGO Share}
- Reduce compliance of ~80% caps uptake of MGO and adds -1MMb/d p.a. to global demand

Source: McKinney Energy Insight
Abatement Technologies

Opting for an alternative fuel like LNG or Methanol is one possibility for meeting the EEDI requirements, but many other technical options are also available. It is therefore assumed that currently, EEDI is not a major driver for LNG as a shipping fuel.

**Sulphur reduction**

- **Combustion modification** (efficiency: 50-60%)
  - It uses the addition of limestone (CaCO3) or dolomite in conventional boiler.

- **Sea Water Scrubbing** (efficiency 95%)
  - It is an extremely efficient method used to reduce Sulphur and PM concentration in exhaust gas.

- **Fresh water Scrubbing** (efficiency 90%)
  - Is an alternative to sea water scrubbing if high efficiency cleaning is needed.

- **Changes in energy system** (N/A)
  - Lead to a lower consumption of Sulphur by energy conservation of fuel substitution.

- **Fuel switching** (efficiency 2.7 to 0.5% = 81%)
  - Low Sulphur diesel (0.5%)
  - Ultra-low Sulphur diesel (0.03%)
  - Alternative fuels: Bio-fuels, natural gas, hydrogen

- **Desulphurization** (N/A)
  - Generally, low-Sulphur fuels go to substitute fuels of the same category having higher Sulphur content.

**Nox Reduction**

1. **Related to nitrogen content of fuels**
   - Internal modification of engines (IEM):
     - Injection retardation
     - Increase of injection pressure
     - Modification of compression ratio
     - Optimization of induction swirl
     - Modification of injector specification
     - Change in number of injector
     - Scavenge/charge air cooling
     - Increasing the scavenge/charge air pressure
   - Water Injection:
     - Water injection
     - Water injection + EGR
   - Exhaust gas circulation
   - Humid air motor (HAM)

2. **Re-burning**
3. **Selective Catalytic Reduction (SCR)**
4. **Plasma Reduction System**
5. **WIFE (water in fuel emulsion)**
Technological challenges for the Shipowners

Strategy of a ship owner on how to cope with environmental requirements and high fuel prices in the coming decade is dependent on which assumptions are most likely to be realized, how other ship owners are likely to act, and the willingness to take risks.

Dual fuel, main engines able to run on either diesel and LNG or diesel and methanol.

It is not only the gas engine itself that has to be considered when one is talking about methane slip, but rather, the entire supply chain must be considered.
Global Scrubbers

983 Vessels with scrubbers installed or on order

- 63% Retrofitted Ships
- 63% Open Loop Scrubbers
- 72 MW Largest Engine Power

Data as of 31 May 2018

Key to bar and pie charts:
- Retrofit Open Loop
- Retrofit Hybrid
- New Build Open Loop
- New Build Hybrid
**LNG Industry – A snapshot**

<table>
<thead>
<tr>
<th>Category</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Global LNG Trade</td>
<td>293.1 mtpa</td>
</tr>
<tr>
<td>Global Liquefaction Capacity</td>
<td>19 countries, 369 mtpa</td>
</tr>
<tr>
<td>Global Regasification Capacity</td>
<td>31 countries, 851 mtpa</td>
</tr>
<tr>
<td>Global FSRU Fleet</td>
<td>In service – 27, On order - 7</td>
</tr>
<tr>
<td>Global LNGC Fleet</td>
<td>In-service – 480, On-order - 116</td>
</tr>
<tr>
<td>Yearly Average price of LNG</td>
<td>US$6.85/MMBtu, Basis DES Asia</td>
</tr>
<tr>
<td>Yearly Average LNGC Charter Rate</td>
<td>DFDE - US$44500 per day, ST – US$26700 per day</td>
</tr>
</tbody>
</table>

**Current state of LNG Markets**

- **Traditional LNG market**
  - Balancing physical market
  - Few buyers
  - Sellers are mostly producers
  - Few risk management tools
  - Illiquid spot markets
  - Pricing is via formula, usually oil linked

- **Market in transition**
  - Growth of spot trading from naturals and speculators
  - Rising number of market participants
  - Rise of basic risk management options
  - Fragmented pricing

- **Commoditized market**
  - Consolidated pricing
  - Spot market pricing sets term contracts
  - Tools to hedge multiple risks
  - Liquid spot and financial markets
  - Wider access to infrastructure

**What is needed to make the leap?**
- More Liquidity
- Consolidated Pricing
- Hedging tools to manage risks
- Destination flexibility

**Spot/Short term trade = 88mtpa or 30% of total trade**
LNG: Commercial & Technical Factors To Consider

**COMMERCIAL**

Which infrastructure investment model works best?
What guarantees are there for investors?
What size should a LNG bunker barge be?
How will LNG bunkers be traded? Mass, Volume or Energy content?
Who will be responsible for the Custody Transfer? Seller or Buyer?
Who will pay for the BOG and BOG management?
Who will pay for the time for inerting of filling lines?
Who will monitor gas quality? Existing bunker surveyors?
Trained personal availability?
Will we develop standards for delivered temperature and pressure?
Does colder gas have a higher commercial value than warmer?
If excess BOG generation is reduced by lowering pumping rate, who pays for the extra bunkering time?

**Custody Transfer.**

LNG Pricing

**TECHNICAL**

Manpower Competency

*Gas grade/class/quality/measurement*

Ship design optimization (cradle to grave philosophy)

Total Energy Management

Risk Management
  ➢ HAZID
  ➢ HAZOP

BOG Management

Filling Operations - the last metre

Ice and moisture.

*Tank cooling issues*

Rollover / Stratification

*Supply source composition differences – mixing of different specs LNG?*

*Difference in Methane Number*

As per IGF code #6.9, in case vessel is not fitted with a Type C tank, calls for BOG system management irrespective of the fact that whether it is used or not used.
Global Gas Prices: three different models

The delta between wholesale and retail prices is still significant for LNG - very small for crude oil-based fuels.

It is possible that this delta may significantly reduce with competition, bringing gas priced LNG down by $200 – 250 / tonne, which would be competitive with MGO at current levels.
Custody transfer: Flowchart to determine the energy transferred.

LNG fuel qualities – variable composition

Worldwide LNG composition

<table>
<thead>
<tr>
<th>LNG export terminals</th>
<th>C1</th>
<th>C2</th>
<th>C3</th>
<th>C4</th>
<th>C5+</th>
<th>N2</th>
<th>LHV [MJ/kg]</th>
<th>MN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arun (Indonesia)</td>
<td>89.33</td>
<td>7.14</td>
<td>2.22</td>
<td>1.17</td>
<td>0.01</td>
<td>0.08</td>
<td>49.4</td>
<td>70.7</td>
</tr>
<tr>
<td>Arzew (Algeria)</td>
<td>87.4</td>
<td>8.6</td>
<td>2.4</td>
<td>0.05</td>
<td>0.02</td>
<td>0.35</td>
<td>49.1</td>
<td>72.3</td>
</tr>
<tr>
<td>Badak (Indonesia)</td>
<td>91.09</td>
<td>5.51</td>
<td>2.48</td>
<td>0.88</td>
<td>0</td>
<td>0.03</td>
<td>49.5</td>
<td>72.9</td>
</tr>
<tr>
<td>Bintulu (Malaysia)</td>
<td>91.23</td>
<td>4.3</td>
<td>2.95</td>
<td>1.4</td>
<td>0.02</td>
<td>0.12</td>
<td>49.4</td>
<td>70.4</td>
</tr>
<tr>
<td>Bonny (Nigeria)</td>
<td>90.4</td>
<td>5.2</td>
<td>2.8</td>
<td>1.5</td>
<td>0.02</td>
<td>0.07</td>
<td>49.4</td>
<td>69.5</td>
</tr>
<tr>
<td>Das Island (Emirates)</td>
<td>84.83</td>
<td>13.39</td>
<td>1.34</td>
<td>0.28</td>
<td>0</td>
<td>0.17</td>
<td>49.3</td>
<td>71.2</td>
</tr>
<tr>
<td>Lumut (Brunei)</td>
<td>89.4</td>
<td>6.3</td>
<td>2.8</td>
<td>1.3</td>
<td>0.05</td>
<td>0.05</td>
<td>49.4</td>
<td>70.6</td>
</tr>
<tr>
<td>Point Fortin (Trinidad)</td>
<td>96.2</td>
<td>3.26</td>
<td>0.42</td>
<td>0.07</td>
<td>0.01</td>
<td>0.01</td>
<td>49.9</td>
<td>87.4</td>
</tr>
<tr>
<td>Ras Laffan (Qatar)</td>
<td>90.1</td>
<td>6.47</td>
<td>2.27</td>
<td>0.6</td>
<td>0.03</td>
<td>0.25</td>
<td>49.3</td>
<td>73.8</td>
</tr>
<tr>
<td>Skida (Algeria)</td>
<td>91.5</td>
<td>6.64</td>
<td>1.5</td>
<td>0.5</td>
<td>0.01</td>
<td>0.85</td>
<td>49</td>
<td>77.3</td>
</tr>
<tr>
<td>Snorre (Norway)</td>
<td>91.9</td>
<td>5.3</td>
<td>1.9</td>
<td>0.2</td>
<td>0</td>
<td>0.6</td>
<td>49.2</td>
<td>78.3</td>
</tr>
<tr>
<td>Wilhelmina (Australia)</td>
<td>89.02</td>
<td>7.33</td>
<td>2.56</td>
<td>1.03</td>
<td>0</td>
<td>0.06</td>
<td>49.4</td>
<td>70.6</td>
</tr>
</tbody>
</table>

Note the variation of Methane Number (MN) 69.5 – 87.4

1% uncertainty on total value of global trade of LNG (200 mtpa in 2010)


AVL method - AVL Inc. developed a method to calculate the methane number, based on experimental measures of different gas mixtures (up to C6, H2, CO2 & SH2).
LNG Ageing or weathering

**Graph 1:**
- **Start of voyage:**
  - 10.95% N2
  - 88.83% CH4
  - 0.22% C2H6
  - => MN 102

- **End of voyage:**
  - 4.96% N2
  - 95.00% CH4
  - 0.03% C2H6
  - => MN 101

**Graph 2:**
- **Start of voyage:**
  - 1.53% N2
  - 97.52% CH4
  - 0.95% C2H6
  - => MN 96

- **End of voyage:**
  - 1.18% N2
  - 88.61% CH4
  - 10.24% C2H6
  - => MN 79

**Table:**

<table>
<thead>
<tr>
<th>Vessel</th>
<th>Bunker Capacity</th>
<th>Range @ full power (-162°C)</th>
<th>Range @ full power (-126°C)</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small Ferry</td>
<td>50m³</td>
<td>39 hours</td>
<td>34 hours</td>
<td>- 5</td>
</tr>
<tr>
<td>Offshore Vessel</td>
<td>1500m³</td>
<td>236 hours</td>
<td>203 hours</td>
<td>-33</td>
</tr>
<tr>
<td>Cont Vessel</td>
<td>10,000m³</td>
<td>793 hours</td>
<td>681 hours</td>
<td>-112 (4.5 days)</td>
</tr>
</tbody>
</table>

**Table 2:**

<table>
<thead>
<tr>
<th>LNG State</th>
<th>Location</th>
<th>Temperature</th>
<th>Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard LNG</td>
<td>Terminal</td>
<td>-163 Celcius</td>
<td>1 bar</td>
</tr>
<tr>
<td>Cold LNG</td>
<td>Intermediate storage</td>
<td>-150 Celcius</td>
<td>3 bar</td>
</tr>
<tr>
<td>Saturated LNG</td>
<td>Customer</td>
<td>-130 Celcius</td>
<td>8 bar</td>
</tr>
</tbody>
</table>
BOG Creation by design

BOG is generated while bunkering or loading.

<table>
<thead>
<tr>
<th>Tank Size</th>
<th>60m³</th>
<th>1000m³</th>
<th>1000m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quantity in Tank at Start (Heel) (m³)</td>
<td>6</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Pressure (Bar)</td>
<td>9</td>
<td>9</td>
<td>Atms</td>
</tr>
<tr>
<td>Temperature (°C)</td>
<td>-126</td>
<td>-126</td>
<td>-162</td>
</tr>
<tr>
<td>Loading Rate (m³/hr)</td>
<td>2</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Loading Time (hrs)</td>
<td>30</td>
<td>10</td>
<td>2</td>
</tr>
<tr>
<td>Boil of Gas Generated (m³)</td>
<td>3.25</td>
<td>53.8</td>
<td>1.4</td>
</tr>
<tr>
<td>Average Boil Of Gas Rate (m³/hr)</td>
<td>0.1</td>
<td>5.4</td>
<td>0.14</td>
</tr>
<tr>
<td>Max BOR (m³/hr)</td>
<td>7</td>
<td>20</td>
<td>0.6</td>
</tr>
<tr>
<td>Min BOR (m³/hr)</td>
<td>1</td>
<td>2.5</td>
<td>0.06</td>
</tr>
<tr>
<td>Boil of Gas Generated (kg) @-162</td>
<td>2</td>
<td>33.2</td>
<td>0.865</td>
</tr>
<tr>
<td>Boil Off Gas as CO₂ Equivalent (kg)</td>
<td>42</td>
<td>697</td>
<td>18</td>
</tr>
</tbody>
</table>

BOG = Boil of Gas
Ice and Moisture

- When transferring LNG the moisture in the air surrounding transfer equipment like flanges, connectors and hoses condensates on the cold parts and freezes to frost or ice.
- This concern especially bunker vessels or bunker facilities that are or will be frequently used and the transfer equipment does not have time to dry by itself.
- LNG systems contain filters that shall capture ice. If ice or moisture still gets into the LNG system, such as a tank, it will be a serious problem.

If flanges and connectors are not warmed and dried sufficiently and if hoses not air free or filled with NG or nitrogen (N2) the condensed moisture, frost and ice may come into the LNG stream and into LNG tanks and further into the fuel systems. (Cryo has introduced a limit for water vapour in air at -40 C or 125 ppm)
And what could happen if the staff is not properly trained

**LNG Spill - Metal Fracture**

Carbon steel will become brittle and crack when in contact with LNG. So will you and your equipment!
Cost to construct a LNG storage tank varies between US$1500-$2000/cum – for 20000 cum tank = US$30-40 million.

Delivery cost per tonne basis (Medium Scale) facility: $137/t or 22% of total cost of LNG fuel price.
### Operational facilities

<table>
<thead>
<tr>
<th>Europe</th>
<th></th>
<th>Americas</th>
<th></th>
<th>Asia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rotterdam</td>
<td></td>
<td>Montreal</td>
<td></td>
<td>Singapore</td>
</tr>
<tr>
<td>Hammerfest</td>
<td></td>
<td>Jacksonville</td>
<td></td>
<td>Kochi</td>
</tr>
<tr>
<td>Barcelona</td>
<td></td>
<td>Port Fourchon</td>
<td></td>
<td>Yokohama</td>
</tr>
</tbody>
</table>

### Planned facilities

<table>
<thead>
<tr>
<th>Europe</th>
<th></th>
<th>Asia</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Gibraltar</td>
<td></td>
<td>Busan</td>
<td></td>
</tr>
<tr>
<td>Dunkirk</td>
<td></td>
<td>Zhoushan</td>
<td></td>
</tr>
<tr>
<td>Hamburg</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
LNG as ship fuel Fleet

LNG FUELLED FLEET BY VESSEL TYPE

- Operating area ships in operation
  - Norway: 56%
  - Europe: 18%
  - America: 11%
  - Asia & Pacific: 8%
  - Middle East: 7%

- Operating area confirmed orderbook
  - Norway: 19%
  - Europe: 17%
  - America: 11%
  - Asia & Pacific: 3%
  - Middle East: 1%

Charts updated 1 October 2018
Methanol is a “future proof molecule that can be made from conventional fossil sources and emerging renewable feedstocks.

Expansion of energy markets for methanol builds demand for sustainably sourced and locally produced methanol.
Methanol

- Liquid at atmospheric pressure
- Available in many ports around the world and along rivers
- Low infrastructure cost
- Flexible, modular system
- Environmentally friendly as it’s biodegradable
- Is plentiful, available globally
- Can be made 100% renewable
- Runs well in existing engine technology and has potential for further optimization
- Complies with increasingly stringent emission reduction regulations
- Requires only minor modifications to current bunkering infrastructure
- Is biodegradable!
- Safe handling can rely on long history and experience in shipping and industry
- Cost are relatively modest and drop as experience mounts
- Shows slight regional price variation
METHANOL: WIDE AVAILABILITY & LOW INFRASTRUCTURE COSTS

- Current bunkering infrastructure needs only minor modifications to handle methanol.
- Infrastructure costs are relatively modest compared to potential alternative solutions. Estimated costs for constructing a 20,000 CuM storage tank US$ 2-4 million (depending on the location and country).
- Bunkering and distribution costs are estimated to be in a range of $30-40 per tonne.
- In the case of Stena Germanica – bunkering to the ship is carried out by specially built pump station at a estimated cost of around €400,000 (Stefenson, 2015) no storage tanks were constructed.
Methanol: Engine Technology and Modification to the Ship

**THE GERMANICA – RESULTS**

- **Nox** 3-5g/kWh (Low Tier II, no major conversion)
- CO <1g/kWh
- PM only from MGO pilot fuel (FSN ~ 0.1)
- Sox only from MGO pilot fuel (99% reduction)
- Formaldehyde emissions (below TA-luft)
- No formic acid detected in exhaust gas
- No reduction in output and load response unchanged, full fuel redundancy
- Higher efficiency (testing showed lower fuel consumption in methanol mode)

**Methanol or diesel can be selected or re-selected as primary fuel quickly and reliably, without the need to stop the engines and without loss in engine speed or output**
Methanol Experience: Stena’s Experience on Ferry “STENA GERMANICA” converted in 2016 to use Methanol as fuel

Why methanol?
• Clean fuel
• Large commodity
• Feedstock is natural gas (Natural Gas)
• Methanol is soluble in water.
• Methanol is sustainable fuel.
• Bio-methanol has near zero carbon footprint.
• Easy to handle (liquid)
• Economically feasible

Challenges
• Low flashpoint
• Toxic
• Low viscosity
• Corrosive
• Low energy content (half compared with oil)

Conclusions after >2000 running hours on methanol:
• Some technical issues with pipe connections due to low viscosity.
• Vibrations in high pressure pipes recalculated and fixed
• Sensitive control and alarm system needed to be fine tuned
• Failing injectors due to under dimensioned spring re-designed
• Methanol works fine as marine fuel
• Very few technical issues - but they are time consuming
METHANOL AS MARINE FUEL EXPERIENCE: WATERFRONT SHIPPING COMPANY

• Commercial-ready MATURE technology
• In 2016, Waterfront Shipping launched seven vessels with methanol dual-fuel MAN ME-LGI 2-stroke engines.
• WFS have 4 additional vessels on order.
• Tankers are owned by Multiple ship owners

The world’s first seven methanol-fueled tankers

WFS Vessel Results: Emission Reductions

For every 1 hour running on methanol, emissions have been reduced by:

- NOx 34% (~83kg)
- SOx 85% (~47kg)
- Particulate Matter 85% (~6kg)

Taking 33 Heavy Duty trucks off the road for one day (NOx)
## Alternate Fuels Comparison

<table>
<thead>
<tr>
<th>Alternative Fuels</th>
<th>MGO + Scrubber</th>
<th>MGO</th>
<th>LNG</th>
<th>Methanol</th>
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<tbody>
<tr>
<td>Investment</td>
<td>Median</td>
<td>Low</td>
<td>High</td>
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<tr>
<td>Fuel Cost Relation</td>
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<td>Median</td>
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<tr>
<td>Fuel Storage Space</td>
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<td>Additional Equipment</td>
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<td>Machinery and Piping</td>
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<td>Additional Risk Investigation</td>
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<td>Sludge Handling</td>
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<td>Median</td>
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<td>Additional Chemicals</td>
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<td>Pollution Risk</td>
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<td>Yes</td>
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</tbody>
</table>
Super ECO 2030
Concept study for large container vessel (NYK) various technologies incl. fuel cells (claiming 32% less CO2 due to fuel cells).

GI (Zero Emission Feeder)
Concept study of Germanischer Lloyd fuel cells + batteries (Technology 2010)

Zero-Emission Scandlines project (futureShip design) Hydrogen powered fuel cells. Use excess windpower to generate hydrogen.

The use of Carbon Capture Systems (CCS) on board of ships was investigated in the Eurostar project of DNV and PSE. The project, that was concluded in 2013, successfully developed a concept design for on-board chemical capture, liquefaction and temporary storage of CO2 for ships in transit until discharge into transmission and storage infrastructures at the next suitable port.

The results show that the concept is technically feasible and capable of reducing maritime CO2 emissions by up to 65%.

For a Very Large Crude Carrier (VLCC), this could correspond to capturing more than 70,000 tonnes of CO2 per year, transforming them from emissions to a tradable product.
Methanol: Potential to address the GHG (CO2 Emissions) requirements
Methanol Economy

Carbon-neutral cycle

Energy in
Methanol synthesis
CO₂ + 3H₂ → CH₃OH + H₂O

Energy out
Renewable Hydrogen

Carbon in
CO₂ from fossil fuel burning power plants

Carbon out
Fuel use
CH₃OH + 3/2O₂ → CO₂ + 2H₂O


BON-NEUTRAL Methanol, Gasoline, Diesel, Jet Fuel, from CO₂ and Water

Professor Georg A. Olah
Nobel Price Chemistry 1994
**CRI: Emission-to-liquid (ETL) Technology** (Patented by Carbon Recycling International)

**Emission-to-liquid** 5 technological building blocks in the patented process by Carbon Recycling International.

1. The CO2 in the waste gases is piped from the points of emission at the stack to the purification system. The removal of impurities is completed in steps.

2. The hydrogen generation system is engineered with the state of the art electrolyzers technology by modules allowing expansion of the plant.

3. The conversion of syngas – a mixture of hydrogen and carbon dioxide – is pressurized to the targeted pressure and mixed to the ratio of 3 to 1.

4. The system of methanol synthesis is engineered to have flexible capacity to adapt to the possible addition of modules of electrolyzers at a later phase.

5. The distillation column is designed to purify the renewable crude to a proprietary fuel grade renewable methanol for blending with gasoline.
1. CRI’s patented technology can convert up to 100% of emissions from an industrial manufacturing or power generating facility.

2. Currently the pilot plant at Iceland uses about 10% of emissions emitted from the Geothermal powerplant it gets the CO2 from.

3. This capacity is scalable. For this particular production facility, CRI would need to upscale its capacity to generate more hydrogen, by adding more electrolyzers. **For each 1 ts of renewable methanol produced, 1,45 ts CO2 and 0,2 ts hydrogen is required.**

4. All CO2 that enters CRI process is converted into methanol in a one-step catalytic reaction. If the reaction does not occur in the first application of the syngas (CO2 and H2), a loop circulation is initiated where the remaining syngas goes through compression again and is re-applied to the reactor.

**Future Development**

We are far along in developing a project in Norway, where CRI will build a 100,000 t plant.
Another leading process for CO2 to Methanol that can be used:

Pilot Plant Location: Osaka Japan
Company: Mitsui Chemical Inc. of Japan
Begin operation in: 2009
Feedstock: 150-160 tpy CO2 from chemical plant emissions
Annual yield: 33000 USGallons of Methanol
Plant utilizes nearly 82% of the CO2 emissions, remaining 18% was looped back for reprocessing. Plant is scaleable.
Various Technologies for CO2 to Methanol

CO2 Recovery & Utilization

Option 1

Flue gas
CO2

Option 2

H2, CO

Methanol

Methanol

QAFAC Utilization of Recovered CO2

- 500 MTPD of CO2 is recovered from the flue gas using MHI's proprietary KS-1™ solvent and injected in synthesis loop for boosting Methanol production.
- The capacity of Methanol Plant has increased by 300 MTPD with addition of CO2 in synthesis gas mixture as excess H2 is available for the methanol reaction.
- Thus, QAFAC's Methanol Plant became Self-sufficient for raw material (CO2).

MHI's Flue Gas CO2 Recovery Process

Flue Gas Outlet

CO2 Purity 99.9%

Absorber

Stripper (Regeneration)

CO2, H2, N2

Pre-treated Flue gas

Excess H2 in Reformed Gas

MeOH Production Increase

CO2 extraction from Flue Gas by CDR route & Injection in Methanol Plant
Conclusion

Shipowners need to get the complete picture and understand the fundamentals (commercial, technical and environmental) of alternate fuels before opting to spend millions on conversion.

In comparison to LNG – methanol is easier to handle marine fuel and conversion and maintenance is much less expensive.

Further regulations to limit CO2 emissions remain a real possibility. Methanol has the potential to address this issue going in to the future.

Given the current global economic growth and uncertainty about the future growth, there will be an impact on the scrapping age of the ships. Some sectors may see loss of earnings by 5 to 6 years of earning life of the vessels due to early scrapping, which will affect the payback calculations.
**Headline news**

**Guidelines on Methanol Fueled Vessels**
Rev 1, December 2018

Ships in India soon may run on methanol: Nitin Gadkari

**AMARAVATI:** Ships in India may soon run on methanol as Centre is drawing up plans regard, Union minister Nitin Gadkari said today.

Gadkari also stressed the importance of developing waterways for their cost effectiveness.

"To cut the high cost of logistics in the country, inland waterways are being developed. I major way, methanol will soon be made the fuel for ships.

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Ships: India’s current fuel mix has 98% of vessels running on diesel.

**To cut the high cost of logistics in the country, inland waterways are being developed. I major way, methanol will soon be made the fuel for ships.**

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**Markets**

**Some Oil Refineries Are Getting A Licen to Print Money**

By Bill Oehlke
March 21, 2018, 9:00 AM GMT+4 | Updated on March 21, 2018, 8:11 PM GMT+4

► Sophisticated plans can already comply with 2020 sulfur rules
► Demand and prices for compliant marine diesel fuel are rising

Ready cash-printing machines - the world’s most sophisticated refineries are about to enjoy great times thanks to what might seem like a minor tweak in rules for the type of fuel ships consume.

From 2020, vessels must burn fuel with less sulfur, or alternatively be fitted with equipment to curb emissions of the pollutant. One thing is clear: only a tiny fraction of the merchant fleet will have such gear when the rules enter force, since many shippers argue it’s the responsibility of refiners to sell the right fuel.

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**EGCSA: 983 Ships Opt for Scrubbers**

Scrubber orders full ahead

Merkel allows Coal Commission to delay pre-2020 action

The German Chancellor Angela Merkel has extended the deadline for a much-awaited report from the country’s coal exit commissions. Elections in three coal states in eastern Germany in 2019, as well as lobbying from utilities prompted her to effectively use the opportunity of having a report on pre-2020 action ready before the COP24 climate meeting in Poland next week.

OPSA, staged in the Polish town of Katowice, is the informal name for the 24th Session of the Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC). Delegates will discuss the economics of coal-fired power plants across all regions of the world, and consider opportunities of a staggered exit...

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**EGCSA: 983 Ships Opt for Scrubbers**

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Merkel allows Coal Commission to delay pre-2020 action

By Emma Homa
July 19, 2017 | Commentary | EGCSA Members | by EGCSA Admin

A survey of EGCSA members has revealed that scrubber uptake is rapidly accelerating with the number of exhaust gas cleaning systems installed or on order reaching at 483 as of 31 May 2017.

This follows a wave of recent reports that major ship operators, including OOCL, CMA CGM, Hapag-Lloyd and Stolt for scrubbers. One of the six container carriers has confirmed it will use scrubbing as part of its 2020 portfolio and there are rumours that others will do likewise.

Until relatively recently the largest installed exhaust handling capacity has been for engines powered in the 30MW. However, the latest data shows that this has been well and truly exceeded by a significant hybrid container ship engine. Large capacity scrubbers are not confirmed to retrofit as the maximum size rear to is a hybrid option for a small engine.