FUELING THE MARITIME SECTOR: IMO 2020 AND BEYOND

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Contents

- About MI
- What is Methanol?
- Potential of Methanol as a Marine Fuel
- Conclusion
01 ABOUT MI
02 WHAT IS METHANOL?
SIMPLEST MEMBER OF ALCOHOLS GROUP

An efficient, universal, future-proof, energy carrier that can be sustainably produced in large quantities
Where is Methanol Produced?

Outside China, methanol is typically produced from natural gas.

**Methanol Production**

**World Total**
- 2018 ~ 122mn t nameplate capacity
- 52% Natural Gas
- 35% Heavy Liquids
- 12% Coal

Excludes China's CTO sector

**Rest of World – ex China**
- 2018 ~ 55mn t nameplate capacity
- 97% Natural Gas
- <1% Heavy Liquids
- 3% Coal

Source: Argus
Rest of world methanol production (excluding China) operates to best of abilities. Excess production from the rest of the world is exported to China.

China “generally” represents the high-cost methanol production bloc in the world and operates to meet China demand, less imports received from the rest of the world.

* Excludes China’s CTO sector

Source: Argus
China dominates global methanol industry demand – 54% in 2018

W Europe and N America compete for the 2nd and 3rd spots – top three accounting for 75% of total

Concentrated consumer base, ~30% of demand from top 25 consumers
  - Main consumers are large, global chemical companies and China MTO producers: BASF, Momentive, Celanese, BP, Dow/Dow Corning, Lucite, Evonik, LyondellBasell, SABIC, Sinopec, Ningbo Fund, Jiangsu Sailboat, etc

Industry growth expected at 4.5% per year. The equivalent of 2 world scale methanol units

*Excludes China’s CTO sector

Source: Argus
METHANOL’S TRANSPARENT PRICE INDEXATION PROVIDES HIGH VISIBILITY

Global pricing reference points are readily obtainable

Source: Argus
METHANOL INDUSTRY PRODUCTION CASH COST CURVES

- Methanol industry cash cost curves well compressed
  - Cash cost only, no depreciation, capital recovery or return
  - fob plant gate basis
  - Shipping to destinations can add $20-$60/t, depending on origin and destination

- A slowly rising crude oil forecast drives little change in feedstock costs
  - Industry incremental cash cost of production remains in a narrow band
  - Little opportunity to “driveup” the floor price of the high cost producer increment

- The methanol industry continues to see robust growth
  - ~4-5% into the next decade
  - China continues to dominate industry demand and production
  - Nominal 2-3 “world scale” methanol units needed per year to keep pace with demand growth

Source: Argus
Methanex posts reference prices monthly in Asia and North America and quarterly in Europe.

Realized pricing is lower than reference prices due to discounts specified in contracts.

Higher visibility over fuel costs which lowers the risk profile.

Source: Methanex Corporation
METHANOL COMPETITIVE ON AN ENERGY EQUIVALENT BASIS

- MGO West Coast Avg: LA, San Francisco, Seattle, Vancouver;
- MGO East Coast Avg: New York, Philadelphia, Norfolk, Montreal, Charleston
- Methanol: adjusted to energy equivalent of MGO (2.16 factor)

Source: Platts and IHS Chemical
RENEWABLE PATHWAYS ARE RAPIDLY DEVELOPING
AN EFFICIENT ENERGY CARRIER

LIQUID STORAGE MEDIUM FOR ELECTRICITY & HYDROGEN

Source: Prof. SHIH Choon Fong, NTU, MI
### STAGES OF RENEWABLE METHANOL DEVELOPMENT

<table>
<thead>
<tr>
<th>Methanol category</th>
<th>Commercial</th>
<th>Feasibility and R&amp;D</th>
<th>Stopped or On-hold</th>
</tr>
</thead>
</table>
| Bio-methanol      | • BioMCN (NL)  
                    • Enerkem (CAN)  
                    • New Fuel (DEN)  
                    • Oberon (USA)  
                    • BioMCN (glycerine) (NL)  
                    • Chemrec (SE)  
                    • Range Fuels (USA)  
                    • Schwarze Pumpe (GER)  
                    • Värmlands Metanol (SE)  
                    • Woodspirit (NL)  |
| Renewable methanol | • CRI (IC)  
                    • Innogy (GER)  
                    • bse Engineering (GER)  
                    • Blue Fuel Energy (CAN)  
                    • CRI (CN/GER)  
                    • MefCO2 (GER)  
                    • Infraserv (GER)  
                    • Liquid Wind (SE)  
                    • Port of Antwerp (BE)  
                    • STEAG (GER)  
                    • Swiss Liquid Future (CH)  
                    • ZAST (GER)  
                    • USC (USA)  
                    • Gensoric (GER)  
                    • Neo-H2 (USA)  |
| Hybrid methanol   | • Haldor Topsoe (DEN)  
                    • OPTIMEoH (GER)  |
| Low carbon methanol | • GPIC (BAH)  
                    • Methanex (CAN)  
                    • QAFAC (QAT)  
                    • SABIC (KSA)  
                    • Carbon2Chem (GER)  
                    • FRESME (SE)  
                    • NCF (CN)  
                    • GasTechno (USA)  
                    • Maverick Synfuels (USA)  |
POWER-2-X

The World Energy Council recently estimated a global demand for carbon-neutral synthetic fuels of 10,000-20,000 terawatt hours by 2050, equivalent to 50% of current fossil fuel consumption.

Source: MAN
RENEWABLES WILL BECOME CHEAPER THAN EXISTING COAL & GAS IN MOST REGIONS BEFORE 2030

- By 2030, new-build renewables will outcompete existing fossil fuel generation on energy cost in most countries—one of the key tipping points in the energy transition.

- The majority of countries will reach this tipping point in the next ~5 years.

- US Northwest is the exception to this with tipping points post-2035, driven by relatively low fossil fuel prices as well as low solar potential.

1 Power generation from existing coal and gas power plants in 2018, as share of total.

FOUR MAJOR SHIFTS AND ONE CONTINUITY ARE SHAPING GAS DEMAND UNTIL 2035

1. **Power**: Further gas demand growth in power will be limited to less than 100 bcm due to increasing competitiveness of renewables. Investments in new renewable generation capacity outpaces gas by roughly a factor of 4.

2. **China**: China’s gas demand growth is greater than that of the next 10 largest growth countries combined, including the US, and represents nearly half of global demand growth through 2035. This growth is driven by an ambitious 5-year plan of the Chinese government that is focused on pushing gas across sectors to replace coal (e.g., boiler switches in buildings).

3. **Middle East**: Previously the growth region, gas demand in the Middle East peaks before 2030 despite continued industry growth, primarily driven by the improving economics of renewables in power and the opportunity cost of exporting gas rather than using it for domestic power generation. The current growth of gas demand as it replaces oil in power is thus short-term in the 2020s.

4. **Chemicals**: The fundamental growth of chemicals demand, in combination with low gas prices in key markets like the US, Russia, and Iran, enable accelerated growth that adds ~200 bcm—significant growth from gas as feedstock for ammonia and methanol.

5. **Transport**: Will continue to see very high growth rates in transport demand enabled by emissions regulation for marine fuels. However, the small base means transport cannot offset the trends in all other sectors.

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ENERGY SOURCE AND MARINE FUELS MIX ASSUMED IN A RENEWABLES DOMINATED PATHWAY

- By 2030, renewable electricity would need to be available at a price of approximately 19 $/megawatt hour

Source: Lloyd’s Register Report
RELATIVE COMPETITIVENESS OF ZEVs USING ELECTRO-FUELS FOR A SMALL-MEDIUM SIZED CONTAINER SHIP

Lower risk profile as investments are more closely associated with running costs (fuel) vs CAPEX

Source: Lloyd’s Register Report
POTENTIAL OF METHANOL AS A MARINE FUEL
BROADLY, METHANOL IS...

- Cost effective and “future proof” fuel which can be produced from a variety of feedstocks – to include renewables

- One of the top 5 seaborne chemical commodities – safely handled for over 50 years

- A lower cost alternative for converting vessels to methanol – minimal and economically viable without subsidies

- Widely available and alleviates many infrastructure limitations both on land and at sea, trading within a narrower price range than competing fuels

- Not as well understood as a vessel fuel, even though it has similar handling characteristics as distillate fuel
# METHANOL FUEL CHARACTERISTICS

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Petrol C&lt;sub&gt;5&lt;/sub&gt;-C&lt;sub&gt;12&lt;/sub&gt; Hydrocarbon</th>
<th>Diesel C&lt;sub&gt;10&lt;/sub&gt;-C&lt;sub&gt;21&lt;/sub&gt; Hydrocarbon</th>
<th>Natural Gas CH&lt;sub&gt;4&lt;/sub&gt;</th>
<th>Methanol CH&lt;sub&gt;3&lt;/sub&gt;OH</th>
<th>Ethanol C&lt;sub&gt;2&lt;/sub&gt;H&lt;sub&gt;5&lt;/sub&gt;OH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass Fraction</td>
<td>C 85</td>
<td>H 15</td>
<td>O 0</td>
<td>37.5</td>
<td>52.2</td>
</tr>
<tr>
<td>Density (liquid)(kg/L)</td>
<td>0.72-0.78</td>
<td>0.82-0.86</td>
<td>0.42-0.46</td>
<td>0.79</td>
<td>0.81</td>
</tr>
<tr>
<td>Boiling point (°C)</td>
<td>30-190</td>
<td>180-360</td>
<td>-162</td>
<td>65</td>
<td>78</td>
</tr>
<tr>
<td>Flash point (°C)</td>
<td>-50 ~-20</td>
<td>&gt;55</td>
<td>-188</td>
<td>11</td>
<td>9</td>
</tr>
<tr>
<td>Auto-ignition point (°C)</td>
<td>420</td>
<td>250</td>
<td>650</td>
<td>465</td>
<td>426</td>
</tr>
<tr>
<td>Lower heating value (MJ/kg)</td>
<td>44.0</td>
<td>42.5</td>
<td>50</td>
<td>19.5</td>
<td>25</td>
</tr>
<tr>
<td>Octane number</td>
<td>70-97</td>
<td>20-30</td>
<td>130</td>
<td>111</td>
<td>108</td>
</tr>
<tr>
<td>Cetane number</td>
<td>-15</td>
<td>40-55</td>
<td>Low</td>
<td>3-5</td>
<td>8</td>
</tr>
<tr>
<td>Flammability limits (%)</td>
<td>1.1-5.9</td>
<td>1.58-8.2</td>
<td>5-15</td>
<td>6-36.5</td>
<td>4-19</td>
</tr>
<tr>
<td>Vapour pressure at 37°C/kPa</td>
<td>55-103</td>
<td>&lt;1.37</td>
<td></td>
<td>31.6</td>
<td>15.8</td>
</tr>
</tbody>
</table>
KEY DIFFERENCES BETWEEN GAS & LIQUIDS

- Compared to gaseous fuels, the key differences with liquids are:
  - Faster pressure release
  - Less product release
  - Localised diffusion
  - Ease of detection and cleaning
PRACTICAL SOLUTION

- Methanol can be a practical solution for dual fuel applications, to include other alternative fuels such as LPG and LNG
- Multi – fuel engines will be the norm going forward
- Methanol can be readily and safely applied in both new build and conversion

Source: Westfal-Larsen
Methanol (MeOH) achieves low emissions & acts as a bridge in lowering CO$_2$ now and in the future (blending renewable or bio methanol)
Approximately 25-40% water is added to the methanol to achieve a new, Tier III solution.

NOx decreases almost linearly with water content, to approximately 2 g/kWh at 50% and 75% load.

Similar system is being planned for fuel oil, so the Tier III compliant technology will be available as a dual fuel solution.

R&D testing completed - service test is under preparation.

Source: MAN
ONLINE FUEL EVALUATOR

Co-developed with LR, has proved to be a valuable tool in comparing economic viability across a range of vessel types, voyages and fuel price scenarios

METHANOL IS ALREADY WIDELY AVAILABLE

MI is currently developing an availability platform together with DNV GL, to highlight the existing availability of methanol globally at more than 100 locations.
PROVEN EXPERIENCE

**DUAL FUEL**
- 7x +4
  - chemical tankers
  - MOL, WL, Marinvest
  - 2 stroke MAN
  - new build
  - retrofit
- 1x
  - ROPAX ferry
  - Stena Line
  - 4 stroke Wärtsila
  - retrofit
- 1x
  - Pilot boat
  - Swedish Maritime Admin
  - high speed Scania, Weichai, a.o.
  - retrofit

**FUEL CELL**
- 1x
  - Tourist boat
  - Innogy
  - Serenergy fuel cells propulsion
  - retrofit
- 1x
  - Ferry
  - Viking Line
  - hotel load
  - retrofit

**PROJECT and R&D**
- Cruise ships, fishing boat, barge, dredge, a.o.
- SUMMETH/MARTEC, Lean Ships, Methaship, Billion Miles, FiTech, India, PCG Product Vessel, NTU Test Bed Green Maritime Methanol, FastWater
- SI hybrid, dual fuel, etc.
- new build & retrofit
Main risks of methanol on ships

Low flash point
- Flash point 11°C
- Class A liquid (flash point below 28°C)
- Volatile and flammable

Explosive
- Oxygenated fuel (50%)
- Wider flammability limits (6%-36%)
- Low flammability limit

Corrosive
- Causes corrosion on metals such as lead, nickel and cast iron
- Causes plastic and rubber parts to swell

Toxicity
- Inhalation, ingestion and absorption
- Acidosis, damage to optic nerve or effect on central nervous system

Main risks of methanol on ships
# METHANOL BUNKERING RISKS

<table>
<thead>
<tr>
<th>Risks</th>
<th>Countermeasures</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fire</strong></td>
<td>• Fire caused by static electricity: Anti-static measures such as grounding of the pipeline between fueling party and party receiving the fuel</td>
</tr>
<tr>
<td></td>
<td>• Use of explosion-prevention equipment</td>
</tr>
<tr>
<td></td>
<td>• Vapour detection</td>
</tr>
<tr>
<td></td>
<td>• Prohibiting smoking as flame is invisible</td>
</tr>
<tr>
<td><strong>Explosion</strong></td>
<td>• Refueling station should be located on an open deck</td>
</tr>
<tr>
<td></td>
<td>• Purging and inerting of the pipeline</td>
</tr>
<tr>
<td><strong>Fuel leakage</strong></td>
<td>• Use of qualified and certified refueling equipment, including qualified hose</td>
</tr>
<tr>
<td></td>
<td>• Approved emergency cutoff procedures</td>
</tr>
<tr>
<td></td>
<td>• Automatic emergency cutoff system</td>
</tr>
<tr>
<td><strong>Toxicity</strong></td>
<td>• Personnel protection equipment</td>
</tr>
<tr>
<td><strong>Overfilling</strong></td>
<td>• Fuel tank maximum level alarm to immediately close the refueling valve</td>
</tr>
<tr>
<td></td>
<td>• Should be equipped with a pair of sensors on the fuel tank</td>
</tr>
<tr>
<td><strong>System failure</strong></td>
<td>• Manual shutoff valve to shutoff the fuel tank (primary valves)</td>
</tr>
<tr>
<td><strong>Power outage</strong></td>
<td>• Mechanical closure of refueling valve (ESD)</td>
</tr>
</tbody>
</table>
SIGNIFICANTLY SAFER FOR THE ENVIRONMENT

**LC50, LC = LETHAL CONCENTRATION**
Concentration in water, at which half the marine population died within the specified test duration

Safer than Diesel by a factor of 240 times

Methanol[1]
15,400 (mg/l)

Methane[5]
49,9 (mg/l)

Heavy Fuel Oil[3]
79 (mg/l)

Diesel[4]
65 (mg/l)

Gasoline[2]
8,2 (mg/l)

[2] Petrobras/Statoil ASA, Safety Data Sheet, ECHA registration dossier Gasoline
[3] GKG/ A/S Dansk Shell, Safety Data Sheet

Additional Source: Meyer-Werft
BUNKERING TECHNICAL CONSIDERATIONS

(1) Refueling station

- Refueling station should be located on open deck for natural ventilation
- There should be a device for safe disposal of leaked fuel, and skirting and collection tray below the joint for safe collection
- Monitor and control the refueling from a safe location (equipped with overfill alarm and automatic cutoff to monitor bunker level and overfill)
- **Personnel protection (shower and eyewash station for emergency use must be available)**
BUNKERING TECHNICAL CONSIDERATIONS

(2) Refueling system

- Every refueling line near the shore connector should be fitted with a manual shutoff valve and a remote shutoff valve connected in series.
- Should be able to perform gas inerting and degassing of the refueling line.
- Should be equipped to purge the fuel from the refueling line after refueling.
- The ship should be equipped with refueling ESD cut-off system, which can be operated from the ship to be refueled or from the place performing the refueling.
Methanol Liquid Tank (IBC)

<table>
<thead>
<tr>
<th>Cargo</th>
<th>Pollution category</th>
<th>Hazard</th>
<th>Ship type</th>
<th>Tank type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methanol</td>
<td>Y</td>
<td>P</td>
<td>3</td>
<td>2G</td>
</tr>
</tbody>
</table>

- **Y** - Release of tank washing water and ballast water into the sea harms marine resources or human health
- **P** - Hazardous and causes pollution
- **3** - Type 3 ship (single-hull)
- **2G** - Type 2G tank, lowest available integral gravity tank

**Methanol Tanks Solution**

- **Tank type**
  - Integral
  - Independent (including portables)

- **Tank location**
  - Below open deck
  - Enclosed space on open deck
FUEL STORAGE (2 of 3)

Independent Tank

- Double bottom
- Tank location
- Tank

Integral Tank

- Coffer dam
- Fuel preparation room
- Inerting space
- Tank

WWW.METHANOL.ORG

METHANOL INSTITUTE
Proportion of gaseous methanol depends on the rate of evaporation

Evaporation is not boiling; it is a very slow process!
FUEL SUPPLY (1 of 3)

1. Fuel pipeline inside the machine area

- Use of double-walled pipe with fuel in the inner pipe and outer pipe being watertight and airtight

- Mechanical ventilation is performed between the inner pipe and outer pipe, where air is changed at least 30 times an hour

- A suitable fuel vapour detector is installed between the inner and outer pipes

- Double-walled pipe should be connected to a suitable collection tank, which has a liquid fuel detector, to collect leaked fuel
2. Valve layout

- The main fuel line leading to each engine location should be fitted with a manual shutoff valve and an automatic shutoff valve (main fuel valve) connected either in series or integrated together.

- The fuel line leading to each engine should be fitted with a manual shutoff valve (to ensure shutoff during maintenance) and an automatic shutoff valve.

- Venting valve does not require dual shutoffs.
3. Fuel line outside the engine location
   - Prohibited from passing through accommodation areas, service locations, between electrical equipment or control stations
   - When passing through enclosed areas other than those described above (except the fuel preparation rooms), double-walled pipes should be used
   - For methanol/ethanol carriers, the fuel lines in the cargo areas need not conform to the above requirements but should at least conform to IBC

4. Fuel preparation rooms
   - Should be airtight and watertight
   - Should be mechanically ventilated
   - Should be fitted with both fuel vapour detection and liquid fuel detection
# VENTILATION

<table>
<thead>
<tr>
<th>Location</th>
<th>Ventilation Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Double-walled pipes</td>
<td>o Negative pressure mechanical ventilation</td>
</tr>
<tr>
<td></td>
<td>o Ventilate 30 times/hour</td>
</tr>
<tr>
<td>Fuel preparation rooms</td>
<td>o Power and number of fans: ventilation capacity should not fall by more than 50% when a fan</td>
</tr>
<tr>
<td></td>
<td>powered by a separate line from a main switchboard or an emergency switchboard fails</td>
</tr>
<tr>
<td>Fuel valve units</td>
<td></td>
</tr>
<tr>
<td>Fuel tanks</td>
<td>when a group of fans powered by a utility line from a main switchboard or an emergency switchboard fails</td>
</tr>
<tr>
<td>Refueling stations</td>
<td></td>
</tr>
<tr>
<td>Open deck</td>
<td>Good and natural ventilation</td>
</tr>
<tr>
<td>Enclosed or semi-enclosed</td>
<td>When natural ventilation is inadequate, mechanical ventilation systems should be considered</td>
</tr>
</tbody>
</table>
### CONTROL, MONITORING & SAFETY SYSTEMS

<table>
<thead>
<tr>
<th>Location Description</th>
<th>Fuel vapour detector</th>
<th>Liquid fuel leakage detector</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between inner and out pipes of double-walled pipes</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Fuel preparation room</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Location of fuel tanks</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Isolation cabin adjacent to the fuel tanks</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Other enclosures that contain fuel lines but do not have double-walled pipes</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Other locations with fuel installations</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Other enclosures/semi-enclosures where fuel vapour may accumulate</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Airlock</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Based on risk analysis, the ventilation inlets in the accommodation area and machine area where fuel vapour may enter</td>
<td>✓</td>
<td></td>
</tr>
</tbody>
</table>
POTENTIAL OF METHANOL AS A MARINE FUEL

• Capital costs for ship conversion less than LNG and similar to after treatment technologies

• Methanol is already easily and cost effectively stored at any port in the world

• Methanol is one of the top 5 seaborne chemical commodities accounting for 35% of the world seaborne chemical and vegoil trade

• Major engine OEMs confident engines can meet SOx and NOx requirements

• Produced renewably, methanol is a future-proof fuel
THANK YOU