Methanol: An Emerging Alternative Marine Fuel

Gregory Dolan, CEO – Methanol Institute
July 2018
MI History

- The Methanol Institute (MI) was established in 1989 to lobby the US Congress.

- 29 years later, MI is recognized as the trade association for the methanol industry, representing world’s leading methanol producers, distributors and technology companies.
Strategic Partnerships

- European Sustainable Shipping Forum (ESSF)
- International Bunker Industry Association
- Lloyd’s Register
- Dangerous Goods Advisory Council
- American Chemistry Council
- Asian Clean Fuels Association
- China Ministry of Industry & Information Technology
- China Nitrogen Fertilizer Industry Association
- Chinese Association of Alcohol & Clean Ether Fuels & Automobiles
- European Chemical Industry Council (CEFIC)
- Formacare
- Gasification & Syngas Technologies Council
- German Regenerative Methanol Network
- Gulf Petrochemicals and Chemicals Association
- International DME Association
- International Methanol Producers & Consumers Association
- National Biodiesel Board
- National Institution for Transforming India (NITI Aayog)
- Oslo University Hospital
- Peking University Centre for Global New Energy Strategic Studies
- Solar Fuels Institute
Marine Fuel Drivers

✓ **Scale**: Marine sector consumes 370 million metric tonnes of bunker fuel per year.

✓ **Sustainability**: There needs to be a viable pathway to low- & no-carbon marine fuels.

✓ **Price**: Need to be price competitive with current bunker fuels and other alternatives such as LNG.

✓ **Supply**: Fuel needs to be available globally.

✓ **Safety**: Ship operators need to be assured of safe handling on-board vessel and for bunkering.
Broad feedstock range, many applications
Reduced Carbon Initiatives

Advanced reformer utilizes CO₂ from combustion in the synthesis

*Comparable CO₂ emissions for 1G-Coal and 2G-Gas are 3.33 and 0.56 tons respectively
Renewable Pathways

**WHERE IS METHANOL PRODUCED?**

**Renewable Pathways**

1. **Biomass (Wood, MSW, etc)**
   - Fermentation
   - Gasification
   - Biogas
   - Biomethane
   - Reformer

2. **Syngas**
   - Reactor and distillation
   - Bio-methanol
   - Renewable methanol

3. **(Renewable) Electricity**
   - Electrolysis
   - Carbon capture

4. **CO₂**
   - CO₂ Capture

**Alcohol Production**
An Efficient Energy Carrier

Methanol CH₃OH has, on a volume basis, 40% more H₂ than liquid hydrogen at -253°C, and 140% more H₂ than compressed hydrogen at 700 bars.
## Renewable methanol projects different stages of 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>
<tbody>
<tr>
<td><strong>Bio-methanol</strong></td>
<td>• BioMCN (NL) • Enerkem (CAN) • New Fuel (DEN) • Oberon (USA)</td>
<td>• Biogo (GER) • Enerkem (NL) • LowLands Methanol (NL) • Södra (SE)</td>
<td>• BioMCN (glycerine) (NL) • Chemrec (SE) • Range Fuels (USA) • Schwarze Pumpe (GER) • Värmlands Metanol (SE) • Woodspirit (NL)</td>
</tr>
<tr>
<td><strong>Renewable methanol</strong></td>
<td>• CRI (IC) • Innogy (GER)</td>
<td>• Blue Fuel Energy (CAN) • CRI (CN) • InfraServ (GER) • Liquid Wind (SE) • Port of Antwerp (BE) • STEAG (GER) • Swiss Liquid Future (CH) • ZAST (GER)</td>
<td></td>
</tr>
<tr>
<td><strong>Hybrid methanol</strong></td>
<td></td>
<td>• Haldor Topsoe (DEN) • OPTIMEoH (GER)</td>
<td></td>
</tr>
<tr>
<td><strong>Low carbon methanol</strong></td>
<td>• GPIC (BAH) • Methanex (CAN) • QAFAC (QAT) • SABIC (KSA)</td>
<td>• Carbon2Chem (GER) • FRESME (SE) • NCF (CN)</td>
<td></td>
</tr>
</tbody>
</table>
Methanol is a versatile fuel source

- Out of the ~75 million metric tons of methanol sold globally in 2017, energy and fuel uses represent 40% of total demand
- From 2009-2017, direct methanol fuel blending has increased at an annual rate of nearly 23%

**FUELS**
- Neat fuel
- Low blends
- High blends
- GEM
- MTBE
- Biodiesel
- DME & OME
- MTG

**TECHNOLOGIES**
- SI & CI engines
- Turbines
- Fuel cells
- Industrial boilers
- Cook Stoves

**SEGMENTS**
- Road & non-road transportation
- Power & heat generation
- Marine
Methanol Fuel Examples Around the World

- Canada – Waterfront Shipping Vessels
- Iceland – M100 Trials
- USA – methanol motorsport fuel
- UK – EN228 low blend
- Sweden – methanol marine fuel
- Denmark – methanol fuel cells for vehicles
- Eni/FCA M15/E5
- Egypt – M15 Trials
- New Zealand – Introducing M3
- Africa – cooking stoves
- Israel – Power generation & M15 Standard
- India – Methanol Economy Roadmap
- China – M15 to M100, Industrial Boilers
- Australia – GEM fuel
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The Clear Alternative Marine Fuel

Diesel Bunker Fuel  Methanol Marine Fuel
The International Maritime Organization has adopted regulations for SOx and NOx that are transforming the shipping industry.

While 2020 global SOx reductions may be met with low sulfur fuels, the combination of SOx and NOx reductions driving shipboard solutions.

Recent IMO action on greenhouse gas emission reductions further narrow future options for shipping – at least 50% GHG reduction by 2050.
Options available to ship owners

- HFO + scrubbers
- MGO or HFO/MGO Hybrid
- LNG
- Methanol
Examples of vessels running on methanol

### DUAL FUEL

<table>
<thead>
<tr>
<th>Type</th>
<th>Example</th>
<th>Engine Types</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical</td>
<td>MOL, WL, Marininvest</td>
<td>MAN, Wärtsila, Scania, Weichai</td>
</tr>
<tr>
<td>Tankers</td>
<td></td>
<td>2 stroke, 4 stroke</td>
</tr>
<tr>
<td>ROPAX</td>
<td>Stena Line</td>
<td></td>
</tr>
<tr>
<td>Ferry</td>
<td></td>
<td>1x Chemical methanol</td>
</tr>
<tr>
<td>Pilot</td>
<td></td>
<td>1x Chemical methanol</td>
</tr>
<tr>
<td>Boat</td>
<td></td>
<td>1x Chemical methanol</td>
</tr>
<tr>
<td>Cruise</td>
<td></td>
<td>1x Chemical methanol</td>
</tr>
<tr>
<td>SI hybrid</td>
<td></td>
<td>1x Chemical methanol</td>
</tr>
<tr>
<td>Dual fuel</td>
<td></td>
<td>1x Chemical methanol</td>
</tr>
<tr>
<td>R&amp;D</td>
<td></td>
<td>1x Chemical methanol</td>
</tr>
</tbody>
</table>

### FUEL CELL

<table>
<thead>
<tr>
<th>Type</th>
<th>Example</th>
<th>Engine Types</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tourist</td>
<td>Innogy</td>
<td>Serenergy fuel cells</td>
</tr>
<tr>
<td>Boat</td>
<td>Viking Line</td>
<td></td>
</tr>
<tr>
<td>Ferry</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cruise</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SI hybrid</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dual fuel</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R&amp;D</td>
<td></td>
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</tr>
</tbody>
</table>

### 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 Port of Rotterdam Barge
- SI hybrid, dual fuel, etc.
- new build & retrofit
Industry welcomes four new ocean-going vessels capable of running on methanol

• “We are very happy to be working with Waterfront Shipping again on this innovative technology. With seven engines already in operation and proven in the field, this new order confirms the ME-LGI concept as a mature technology. Since this dual-fuel engine entered the market in 2016, its price has dropped considerably, which makes it an even more attractive propulsion option. Allied with its environmental credentials and convenience of use when employing methanol as a fuel, we are confident the ME-LGI will continue its promising progress,” states René Sejer Laursen, Promotion Manager, MAN Diesel & Turbo.

MAN Duel-Fuel Engine Configuration

Fig. 4: ME-LGI system overview
**Sustainable Marine Methanol (Sweden)**

- MI 2015 support of USD$68,000
- The research concluded that there are no obstacles to the efficient use of Methanol in a converted diesel engine and that smaller vessel conversion projects are feasible and cost-effective, with levels of safety that easily meet existing requirements
- Road ferry with an engine capacity of about 350 kW
- Potential for Biomethanol to be progressively blended into the mix as more becomes available
- [http://summeth.marinemethanol.com/?page=reports](http://summeth.marinemethanol.com/?page=reports)

### M/S Jupiter Vessel Particulars

<table>
<thead>
<tr>
<th>Main Dimensions</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Length Overall (LOA)</td>
<td>86 m</td>
</tr>
<tr>
<td>Breadth</td>
<td>14 m</td>
</tr>
<tr>
<td>Depth</td>
<td>3.45 m</td>
</tr>
<tr>
<td>Ramp Length</td>
<td>11 m</td>
</tr>
<tr>
<td>GT</td>
<td>737 tonnes</td>
</tr>
<tr>
<td>Design speed</td>
<td>11.6 knots</td>
</tr>
<tr>
<td>Cargo</td>
<td></td>
</tr>
<tr>
<td>Passengers</td>
<td>397</td>
</tr>
<tr>
<td>Passenger cars</td>
<td>60</td>
</tr>
<tr>
<td>Loading capacity</td>
<td>540 tonnes</td>
</tr>
<tr>
<td>Main Engine</td>
<td>4 x Volvo Penta D12D-C, 331 kW, total installed power is 1324 kW</td>
</tr>
<tr>
<td>Fuel Tank</td>
<td>2 x 28 m³ (diesel) (total capacity 56 m³)</td>
</tr>
</tbody>
</table>
• GreenPilot (Sweden)

  • MI 2015 support of USD$112,000
  
  • Funding from Methanol Institute and Swedish Maritime Administration
  
  • WeiChai 6-cyl, 365kW, M100 converted NG engine provided by FiT, in high-speed, rescue/pilot vessel
  
  • Sea trials started on WeiChai engine in March, which concluded year end, 2017
  
  • WeiChai-powered vessel and converted Scania engine on stand, both exhibited at Nor-shipping on May 30th, 2017
  
  • Closing workshop was 3 May 2018 Gothenburg

Converted WeiChai engine is planned to be used in a Singapore pilot project together with Nanyang Technological University, Q4 2018
METHASHIP: Cruise & RoPax

• MethaShip (Germany)
  
  • 2 designs – cruise and ropax, with Lloyds, Meyer Werft, HELM, Flensburger Schiffbau-Gesellschaft
  
  • MethaShip is a national research project funded by the BMWi (Federal Ministry for Economic Affairs and Energy)
  
  • 45-month project, closed on 28 May 2018
  
  • Recently completed successful truck-to-ship bunkering
  
  • Presented at IMO’s most recent CCC4
  
  • https://www.vsm.de/de/presseinformation/7818
Other Pilot Projects

• Methanex
  • Tianjin University and ZiChai (engine OEM) as partners
  • Converted 1,100kW marine engine with DMCC technology for commercial fishing vessel applications (Tianjin University)

• Billion Miles (Singapore)
  • 4-cyl M100 prototype, skid-mounted, auxiliary power formally launched in 2018
  • Main propulsion unit coming later in 2018

• FiTech
  • Fujian (140kW), fishing vessel (still discussing)
  • MoA multi-vessel, LNG to methanol conversion (still discussing)

• PCG Product Supply Vessel Interest (still discussing)
  • Dual-fuel
  • Small product carrier (5,000 mt)

• NTU’s test bed facility (about to launch)
  • 1st Phase
    • Test bed emissions and fuel consumption analysis
    • Converted WeChai engine with FiT, ScandiNAOS, LR, IBIA, CCS, Keppel
    • No vessel yet, but targeting single-engine, shore-to-ship crew transport vessel

• Plus: EU inland waterways; India fishing boats; Celeste EU methanol fuel cell vessel
Emissions Reductions

*Methanol is among the lowest emission fuels for marine engines*

Source: Stena Lines -- Emission reductions when compared to alternative fuels currently available (fuel oil)
Methanol / Water Blending (Emulsification)

- NOx decreases almost linearly with water content
- NOx emissions are close to 2 g/kWh at 50 and 75% load
- NOx emissions at 25% load is at the “not to exceed limit” for Tier-III, but can be lowered further
- 100% load with high water content not possible due to system limitations

Source: MAN
Future Fuel Pricing

Source: Bunkerindex
Cost Competitiveness

Chart source: Platts and IHS Chemical
- MGO NA GC: Avg New Orleans, Houston; MGO NA WC: Avg LA, San Francisco, Seattle, Vancouver; MGO Europe: Avg Rotterdam, Antwerp, Hamburg; MGO Asia: Avg Shanghai, Korea; MGO Middle East: Avg Fujairah, Kuwait, Khor Fakkan
- Methanol: Avg USGC, China and Europe spot prices, adjusted to energy equivalent of MGO (1.15 factor)
Fuel Comparison Model & Online Calculator

Fuel Choice Calculator

- Vessel Type: Bulk Carrier
- Capacity: 178506 DWT
- Design Speed: 11.7 Kts
- Average loaded DWT: 141204.8 tonnes
- Annual Distance Traveled: 56712 Nm
- Select open or closed loop option for EGCS: Open
- Methane Slip: 3%
- Time spent inside ECA: 50%
- Asset expected life: 25 years
- Annual fuel consumption conventional fuel: 5756.213 mt/y

Calculate

Options:
- Fuel consumption & Costs
- NPV & Total Cost
Fuel Comparison Model & Online Calculator

**Total Fuel CAPEX**:  
- Total CAPEX LNG: 49.766 M USD  
- Total CAPEX HFO scrubbers: 44.167 M USD  
- Total CAPEX Compliant fuel: 42.3 M USD  
- Total CAPEX Methanol: 44.913 M USD

**Price Differentials (USD/MT)**:  
- LNG: 21  
- HFO 3.5: 120  
- Methanol: 100

**Fuel Costs**:  
- **LNG price**: 315 USD/mt  
- **HFO 3.5 price**: 390 USD/mt  
- **MGO 0.50 price**: 550 USD/mt  
- **Methanol price**: 376 USD/mt

**Calorific Value**:  
- Calorific Value LNG: 49 kJ/kg  
- Calorific Value HFO 3.5: 41 kJ/kg  
- Calorific Value Compliant fuel: 43 kJ/kg  
- Calorific Value Methanol: 20 kJ/kg
Available in many ports around the world

Methanol storage capacity estimates (thousand tons)
Methanol is widely available and easy to handle

- 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
IMO IGF Code for Ethyl/Methyl Alcohols

- Not clear when IGF Codes will be Approved (ie; which future CCC X)
- Not clear after IGF Codes will be Approved, at which MSC they could be Adopted In Principle
- IMO has reserved 2024 by which IGF Codes must come into Force
- After Approval, IGF Codes may be implemented at flag state level with the understanding that additional amendments may be added, requiring compliance, before IGF Codes come into Force
## Comparing apples to apples

<table>
<thead>
<tr>
<th>Hazard pictograms (CPL)</th>
<th><strong>METHANOL</strong></th>
<th><strong>DIESEL</strong></th>
<th><strong>GASOLINE</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>![Methanol pictogram]</td>
<td>![Diesel pictogram]</td>
<td>![Gasoline pictogram]</td>
</tr>
</tbody>
</table>

### Signal word: (CPL)
- **Danger**

### Hazard statements (CPL)
- **METHANOL**
  - H227: Flammable liquid and vapour. May cause fire or explosion.
  - H331: Toxic if swallowed.
  - H315: Toxic by inhalation. May cause damage to the liver.
  - H318: Causes serious eye irritation.

- **DIESEL**
  - H226: Flammable liquid and vapour.
  - H302: May be fatally if swallowed and enters the airways.
  - H335: Causes skin irritation.
  - H317: Causes irreversible damage to the lungs.

- **GASOLINE**
  - H224: Extremely flammable liquid and vapour.
  - H315: Causes skin irritation.
  - H331: May cause serious eye irritation.
  - H319: May cause respiratory tract irritation.

### Precautionary statements (CLP)
- **METHANOL**
  - P201: Obtain special instructions before use.
  - P202: Do not breathe or inhale vapour; avoid contact with eyes, face, or skin.
  - P203: Wash thoroughly after handling.
  - P204: Keep out of reach of children.
  - P205: Use only non-sparking tools.

- **DIESEL**
  - P201: Obtain special instructions before use.
  - P202: Do not breathe or inhale vapour; avoid contact with eyes, face, or skin.
  - P203: Wash thoroughly after handling.
  - P205: Use only non-sparking tools.

- **GASOLINE**
  - P201: Obtain special instructions before use.
  - P202: Do not breathe or inhale vapour; avoid contact with eyes, face, or skin.
  - P203: Wash thoroughly after handling.
  - P204: Keep out of reach of children.
  - P205: Use only non-sparking tools.
Less dangerous than gasoline

Methanol Fuels and Fire Safety

Vehicle Fire Risk
In 1986, there were 500,000 vehicle fires and 1,400 vehicle fire fatalities in the United States. Gasoline was the fuel most likely to ignite in 100,000 of these fires and many of the other fires ultimately involved gasoline.

Gasoline-fed fires in 1986 involving cars, buses, or trucks resulted in 790 deaths, 4,089 serious injuries, and $215 million in property damage.

Proposals for the fuel systems of automobiles would drop dramatically if methanol were substituted for gasoline as the nation's primary automotive fuel. Looking just at vehicle fires in which gasoline is the fuel material to ignite, a switch to methanol could save an estimated 730 lives, prevent nearly 3,900 serious injuries, and eliminate property losses of millions of dollars a year.

Methanol’s fire safety advantage over gasoline stems from several physical and chemical properties (see figures on page 2):

- **LOWER VOLATILITY** (Figure 1)
  Methanol does not evaporate or form vapor as readily as gasoline does. Under the same conditions, exposed gasoline will volatilize four to five times more vapor than will exposed methanol.

- **HIGHER FLAMMABILITY REQUIREMENT** (Figure 2)
  Methanol vapor must be four times more concentrated in air than gasoline vapor for ignitions to occur.

- **LOWER VAPOR DENSITY**
  Gasoline vapor is two to three times denser than air, while methanol vapor is only slightly denser than air and disperses more rapidly to non-combustible concentrations.

- **LOWER HEAT RELEASE RATE**
  Methanol burns 25 percent as fast as gasoline and methanol fires release heat at only one-eighth the rate of gasoline fires.

These properties together make methanol inherently more difficult to ignite than gasoline and less likely to cause deadly or destructive fires if it does ignite. Methanol is the fuel of choice for Indianapolis-type race cars, in part because of its superior fire safety characteristics.

Table adapted from Machele, 1998; a 1-No concern. 2 to 3 = Low Level concern. 4 to 6 = moderate concern. 7 to 8 = high-level concern. 9 to 10 = extreme hazard. b Numbers in parenthesis reflect hazard reductions resulting from design changes. c Number in parenthesis incorporates the lowered likelihood of ingestion due to the absence of additives.

Source: Malcolm Pirnie, Inc., Technical Memorandum
Methanol has lower fire risk

Methanol
- evaporates slowly
- needs lots of vapour to burn
- confined fire zone; fires less likely

Gasoline
- evaporates fast
- needs little vapour to burn
- broad fire zone; fires more likely
(LC50, LC=Lethal Concentration):
Concentration in water, at which half the population died within a specified test duration.

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

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

Diesel[4]
65 (mg/l)

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

**Methanol better than**
- **Diesel** by factor **240**
- **Gasoline** by factor **1900**

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

*Additional Source: Meyer-Werft*
# Methanol safer for marine environment

<table>
<thead>
<tr>
<th></th>
<th>Maritime accident</th>
<th>Maritime accident</th>
<th>Simulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ship</td>
<td>Erika</td>
<td>Tanio</td>
<td>-</td>
</tr>
<tr>
<td>Fuel</td>
<td>Heavy Fuel Oil</td>
<td>Heavy Fuel Oil</td>
<td>Methanol</td>
</tr>
<tr>
<td>Released amount</td>
<td>19,000 t</td>
<td>13,500 t</td>
<td>10,000 t</td>
</tr>
<tr>
<td>Affected coastline</td>
<td>400 km</td>
<td>200 km</td>
<td>0 km</td>
</tr>
<tr>
<td>Total damage:</td>
<td>$914M</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Cleaning</td>
<td>$100M</td>
<td>$50M</td>
<td>$0</td>
</tr>
<tr>
<td>Fishing industry</td>
<td>$98.3M</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Tourist industry</td>
<td>$400-500M</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Claim for damages</td>
<td>$120M</td>
<td>$17M</td>
<td>-</td>
</tr>
<tr>
<td>Killed birds</td>
<td>≈ 60,000</td>
<td>≈ 40,000</td>
<td>-&gt; 0</td>
</tr>
</tbody>
</table>

Source: MethaShip
MI Focus: Methanol as a Marine Fuel

- Participate in formation of international regulations and safe handling guidelines for methanol as alternative fuel
- Work with engine OEMs on new build and conversion offerings across multiple scales
- Encourage and support pilot demonstrations of methanol marine fuels in multiple markets, to validate environmental, technical and economic merits
- Direct marketing campaign
Methanol...

• 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
• shows slight regional price variation
• **NEEDED: Vessels, guidelines, standards**