METHANOL AS AN ALTERNATIVE FUEL

Chris Chatterton, COO

ASIAN SULPHUR CAP 2020

24 – 25 OCTOBER 2018
SINGAPORE
- About MI

- Developing Trends for New Capacity

- Global Methanol Fuel Blending

- New Markets

- Methanol as Marine Fuel
01 ABOUT MI
The Methanol Institute (MI) formed in 1989
40+ members internationally
MEMBERS

Tier 1

Tier 2

Tier 3

Mitsubishi International Corporation

Tier 4

MEMBERS
MI STRATEGIC PARTNERS

• China Nitrogen Fertilizer Industry Association
• Asian Clean Fuels Association
• Chinese Association of Alcohol & Clean Ether Fuels & Automobiles (CAAEFA)
• Gulf Petrochemicals and Chemicals Association (GPCA)
• International DME Association (IDA)
• International Methanol Producers & Consumers Association (IMPCA)
• Peking University Center for New Global Energy Strategy Studies
• Lloyd’s Register
• International Bunker Industry Association
• Dangerous Goods Advisory Council
• China Classification Society
DEVELOPING TRENDS FOR NEW CAPACITY
SUPPLY CAPACITY BY REGION

- Merchant projects are focused in USGC
- China future capacity additions may slow, with a focus on integrated facilities

Supply Capacity for Methanol by Region
2012– 2022E

Source: MMSA
CHINA METHANOL DEMAND DRIVES WORLD MARKETS

Projected Methanol Demand Growth, by Product & Region
2017–2027E

Source: MMSA
MTO DRIVING GLOBAL METHANOL DEMAND

Estimated Global Methanol Demand by Derivative
(1Q 2018 MMSA Update – MTO includes integrated facilities)

Forecast

CAGR 12-27E = 5.5%

-000-metric tons

Source: MMSA
**CHINA**

• 2017 total capacity 83.51MMT, 8% increase
  - 7MMT of new capacity expected in 2018, reaching 90MMT by 2019

• Total operational rate 73.6%, another 5.4% increase since 2011

• Shut-in capacity 11.02 MMT [9.26 MMTs (84%) has been idle for 2 years]

• China consumption 69.5 MMT, 12.9% increase
  - Olefin (44%), Formaldehyde (20%), Fuel (13%), DME (6%)

• China imports 8.14 MMT, 7.5% decrease
  - Iran 2.52MMT, New Zealand 1.81MMT and Saudi Arabia 0.8MMT

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**Operating Rates by year**

![Graph showing operating rates from 2011 to 2017]

**Methanol Imports by year**

![Bar chart showing methanol imports from 2012 to 2017]

*Source: CNFIA, CGNESS*
Where is Methanol Produced?

Renewable Pathways

- Bio-methanol
- Gasification
- Biomass
- Electrolysis
- CO2 capture
- CO2

Legend:
- Reactor and distillation
- Gasification
- Electrolysis
- CO2 capture
- CO2

MSF ведет свою деятельность в более чем 60 странах мира.

WWW.METHANOL.ORG
REDUCED CARBON INITIATIVES

METHANOL SYNTHESIS

WHERE IS METHANOL PRODUCED?

0.14 tons CO₂ per ton methanol

Efficient
Economic
Environment-friendly

Natural Gas → Gas-Heated Reformer → Auto-Thermal Reformer → Gas Compression → Methanol Synthesis → Methanol

Advanced reformer utilizes CO₂ from combustion in the synthesis

*Comparative CO₂ emissions for 1G-Coal and 2G-Gas are 3.33 and 0.56 tons respectively
AN EFFICIENT ENERGY CARRIER

LIQUID STORAGE MEDIUM FOR ELECTRICITY & HYDROGEN

CO₂ Capture

CO₂

Synthesis

METHANOL

Recycled through the atmosphere

Reformer

CO₂

Applications for pure CO₂

Emissions

H₂ Generation

H₂

Methanol for storing and distributing electricity and hydrogen.

Other Applications

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.
SMALL-SCALE PRODUCTION: HALDOR TOPSOE

MeOH-To-Go™
Small-scale methanol production

Traditional focus
- Economy of scale
- Focus on energy consumption

Small scale focus
- Reliable, proven, ease-to-operate
- 215 MTPD Methanol, Grade AA and IMPCA specs
- Competitive CAPEX
- Fast on-site construction
- Ease of transportation
SMALL-SCALE PRODUCTION: PRIMUS

• The systems are simple and economical at scales as low as 500 MMBtu/day (83boe/day)

• Feedstocks: flare gas; stranded ethane; pipeline natural gas; excess syngas from underutilized reformers

• Primus has developed a range of flexible gas-to-liquids systems that can produce methanol, DME or gasoline
SMALL SCALE PRODUCTION: GASTECHNO

- The Gastechno process is a non-catalytic gas-to-liquids technology that converts methane to methanol in one step.
- The “Methanol in a Box” system is housed in a 40-foot shipping container.
- Designed to monetize flare gas from 50,000 cubic feet per day to 30 million cubic feet per day (9bpd to 5,100bpd).
The global renewable chemicals market should reach approximately USD 102.76 billion by 2022.*

- Retail consumers are becoming increasingly aware of health and environmental concerns, which translates into a growing demand for greener components or a “cradle to cradle” solution in consumer products.
- Global consumer goods manufacturers are listening to their customers as they demand greener everyday products.
- Global chemical groups, in turn, are looking to add renewable alternative chemicals to their hydrocarbon-based product lines to meet the demand of their own customers.

* Source: Zion Market Research
GLOBAL METHANOL FUEL BLENDING
PRACTICAL LIQUID FUEL

Dominant global transportation fuels, high energy density

A Practical alternative

Low energy density
High on board storage costs

Net gravimetric energy density / [MJ/kg]

Net volumetric energy density / [MJ/l]
Global Transportation Fuel Progress

Israel
- Cooperation with Italy Fiat to promote M15 Fiat 500 Car (Euro 6)
- Testing M70-85 in Flex fuel vehicles
- 2016 First M15 National Standard Released

Italy
- ENI and FCA cooperation to promote A20 fuel (M15+E5)
- Fiat 500 cars for car sharing service in 2018
- Compliance with Euro 6 standard and 3% tailpipe emission reduction

Denmark
- Methanol Fuel Cell for EV range extension
- Europe’s first methanol filling station in Aalborg, Denmark (Aug. 2015)
India: Roadmap to Methanol Economy

- September 2015, NITI Aayog formed the Methanol Economy Expert Group

- Methanol production from coal and biomass, and utilize methanol and DME as transportation fuels

- September 2016, MI jointly organized a Methanol Economy International Seminar held in Delhi

- Launching Projects:
  - M15 fuel blending
  - methanol/DME buses and trucks
  - railway engines
  - inland waterways
  - cook stoves
  - industrial boilers

Union & Road Transport Minister Nitin Gadkari
• Widely used for heating and industrial steam, new-builds and replacing coal and HFO-fired units
• Capacity range from 1 - 20 t/h
• Standards being developed together with MI and Methanex support
• Blends starting as low as 60% (M60)
• Estimated more than 1,000 units currently, consuming over 2M mtpa of methanol

Source: Methanol New Energy Applications in China: Boilers and Cook Stoves
**METHANOL COOK STOVES**

- **Different types of methanol cook stoves:**
  - Single burner heating
  - Stir frying
  - Steaming
- Widely used in restaurants, central kitchens: *mainly cost driven*
- Simple storage and transportation, filling the deficit of NG pipeline capacity
- Fuel:
  - 100% methanol (M100)
  - 80% and higher blends (emulsified with water)
- **Consuming over 3M mtpa of methanol**
METHANOL AS MARINE FUEL
EMISSIONS SCORECARD

• Methanol (MeOH) achieves low emissions & acts as a bridge in lowering CO$_2$ in the future (renewable/bio methanol)
**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*
EMISSION CONTROL AREAS (ECAs)

North America
- SOx established 2009
- Enforced since 2012
- New keels from 2016 NOx compliant

Europe
- SOx established 2005
- Enforced since 2006
- 2015: SOx < 0.1%

China
- 2015: HK ECZ established for OGV
- 2016: PRD ECZ
- 2019: China-wide ECZ

Sources: IMO
IMO CURRENT & FUTURE SULPHUR LIMITS

- IMO:
  - 0.1% in 2015 in existing ECAs in NA & EU
  - 0.5% in 2020 globally

- Predominant shipping fuel is HFO which does not meet limits – methanol is sulphur free

- China phasing in regulations to reduce sulphur, NOx and PM from marine fuels over next few years

- Marine fuels global market size: 650M mtpa methanol equivalent

Source: IMO
FUTURE FUEL MIX

Fuel bunker Forecast
(MDT forecast based on Robin Meech)

Source: Robin Meech
MGO PRICING

Wednesday May 23, 2018
Global Average Bunker Price – MGO : 758.50 $/mt
Global 20 Ports Average – MGO : 729.00 $/mt

Source: Ship & Bunker
FUTURE FUEL PRICING

Bunker Fuel Price

$/MT


Source: Bunkerindex

WWW.METHANOL.ORG
**Fuel Comparison Model & Online Evaluator**

**Fuel Choice Calculator**

<table>
<thead>
<tr>
<th>Vessel Type</th>
<th>Capacity</th>
<th>Design Speed</th>
<th>Average loaded DWT</th>
<th>Annual Distance</th>
<th>Methane Slip</th>
<th>Time spent inside ECA</th>
<th>Asset expected life</th>
<th>Annual fuel consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bulk Carrier</td>
<td>176506 DWT</td>
<td>11.7 Kts</td>
<td>141204.8 tonnes</td>
<td>56712 Nm</td>
<td>3 %</td>
<td>50 %</td>
<td>25 years</td>
<td>5756.213 mt/y</td>
</tr>
</tbody>
</table>

**Additional Options**
- Select open or closed loop option for EGCS
- Fuel consumption & Costs
- NPV & Total Cost
## Fuel Comparison Model & Online Evaluator

### Total Fuel CAPEX

<table>
<thead>
<tr>
<th>Description</th>
<th>Total CAPEX</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>LNG</td>
<td>49.766</td>
<td>M USD</td>
</tr>
<tr>
<td>HFO scrubbers</td>
<td>44.167</td>
<td>M USD</td>
</tr>
<tr>
<td>Compliant fuel</td>
<td>42.3</td>
<td>M USD</td>
</tr>
<tr>
<td>Methanol</td>
<td>44.913</td>
<td>M USD</td>
</tr>
</tbody>
</table>

### Price Differentials (USD/MT)

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>LNG</td>
<td>21</td>
<td>260.0</td>
<td>31</td>
</tr>
<tr>
<td>HFO 3.5</td>
<td>14</td>
<td>185.0</td>
<td>22</td>
</tr>
<tr>
<td>Methanol</td>
<td>11</td>
<td>199.0</td>
<td>22</td>
</tr>
</tbody>
</table>

### Fuel Costs

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>LNG</td>
<td>315 USD/mt</td>
</tr>
<tr>
<td>HFO 3.5</td>
<td>390 USD/mt</td>
</tr>
<tr>
<td>MGO 0.10</td>
<td>600 USD/mt</td>
</tr>
<tr>
<td>Methanol</td>
<td>376 USD/mt</td>
</tr>
</tbody>
</table>

### Calorific Value

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>LNG</td>
<td>49 kJ/kg</td>
</tr>
<tr>
<td>HFO 3.5</td>
<td>41 kJ/kg</td>
</tr>
<tr>
<td>Compliant fuel</td>
<td>43 kJ/kg</td>
</tr>
<tr>
<td>Methanol</td>
<td>20 kJ/kg</td>
</tr>
</tbody>
</table>
ANNUAL FUEL CONSUMPTION & EMISSIONS

Fuel consumption, SOx, and CO2 emissions for different fuel types:
- LNG
- LNG (incl. Methane slip)
- HFO Scrubbers
- Compliant Fuel
- Methanol

The graph shows the tonnage of CO2 and SOx emissions for each fuel type.
GLOBAL PORT TERMINAL AVAILABILITY

Source: IHS 2017
MARINE EXPERIENCE

- March 2015: Stena Germanica – Wärtsilä methanol-fueled marine engine

- Apr 2016: Methanex’s Waterfront Shipping – dual-fuel MAN methanol/diesel engines

- Lloyd’s Register MethaShip project

- LeanShips dual-fuel demo

- Oct 2015: Billion Miles Singapore develops small-marine applications

- Jun 2016: ScandiNAOS Green Pilot Boat conversion
**FLAMMABILITY & TOXICITY**

### Economic Impact - HFO vs Methanol:

<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>

### Takeaways:
- Not more toxic than gasoline or diesel
- Methanol poisoning is treated simply and is not carcinogenic
- No GHG potential (methane slip)
- Miscible in water – a large concentration spill will rapidly decrease with only short term effects
- Far less hazardous to the environment

**TABLE 6-1 HAZARD SUMMARY**

<table>
<thead>
<tr>
<th></th>
<th>M100</th>
<th>Gasoline</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Flammability</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ease of Occurrence</td>
<td>4</td>
<td>9</td>
</tr>
<tr>
<td>Open &amp; Restricted</td>
<td>8 (2-4)</td>
<td>2</td>
</tr>
<tr>
<td>Areas Enclosed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spaces</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Relative Hazard if Fire</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fire Severity</td>
<td>3</td>
<td>10</td>
</tr>
<tr>
<td>Ease of Extinguishing</td>
<td>7</td>
<td>10</td>
</tr>
<tr>
<td>Flame Visibility</td>
<td>8</td>
<td>1</td>
</tr>
<tr>
<td><strong>Toxicity</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inhalation-Low Conc.</td>
<td>3</td>
<td>10</td>
</tr>
<tr>
<td>Toxicity</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Ease of Occurrence</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inhalation - High Conc.</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Toxicity</td>
<td>10</td>
<td>3</td>
</tr>
<tr>
<td>Ease of Occurrence</td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>Skin Contact.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Toxicity</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td>Ease of Occurrence</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Ingestion</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Toxicity</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Ease of Occurrence</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

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Table adapted from Machiele, 1998. ¹ 1-2 concern. 2 to 3 = Low Level concern. 4 to 6 = moderate concern. 7 to 8 = high-level concern. 9 to 10 = extreme hazard. ² Numbers in parenthesis reflect hazard reductions resulting from design changes. ³ Number in parenthesis incorporates the lowered likelihood of ingestion due to the presence of additves.

Sources: Economic, Social & Environmental Effects of the “Prestige” Oil Spill, Meyer-Werft
SAFER FOR THE ENVIRONMENT

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

Better than Diesel by a factor of 240 times
- Methanol\(^{[1]}\)
  - Concentration: 15400 (mg/l)
- Methane\(^{[5]}\)
  - Concentration: 49.9 (mg/l)
- Heavy Fuel Oil\(^{[3]}\)
  - Concentration: 79 (mg/l)
- Diesel\(^{[4]}\)
  - Concentration: 65 (mg/l)
- Gasoline\(^{[2]}\)
  - Concentration: 8.2 (mg/l)

Better than Gasoline by a factor of 1900 times

---

\(^{[1]}\) ECHA, European Chemicals Agency, registration dossier Methanol
\(^{[2]}\) Petrobras/Statoil ASA, Safety Data Sheet, ECHA registration dossier Gasoline
\(^{[3]}\) GKG/ A/S Dansk Shell, Safety Data Sheet
\(^{[4]}\) ECHA, European Chemicals Agency, registration dossier Diesel
\(^{[5]}\) ECHA, European Chemicals Agency, registration dossier Methane

Additional Source: Meyer-Werft
IMO CONFIRMATION OF ETHYL/METHYL ALCOHOLS

CCC 1
• Establish CG to develop measures for:
  o Ethyl/methyl alcohol
  o Fuel cells
  o Low-flashpoint diesel

CCC 2
• Consider establishing WG to develop measures for:
  o Ethyl/methyl alcohol
  o Fuel cells
  o Low-flashpoint diesel
• Consider re-establishing CG
• Consider the need for other sub-committees to examine drafts or parts of them and, if so, make the necessary request to the relevant sub-committee(s)

CCC 3
• Consider establishing WG to finalize measures for:
  o Ethyl/methyl alcohol
  o Fuel cells
  o Low-flashpoint diesel

CCC 4
• Approval
• Consider establishing WG to finalize measures for:
  o Ethyl/methyl alcohol
  o Fuel cells
  o Low-flashpoint diesel
• Not Approved

CCC 5
• Approval
• Consider establishing WG to finalize measures for:
  o Ethyl/methyl alcohol
  o Fuel cells
  o Low-flashpoint diesel

MSC 97
• Approval
• Not Approved

MSC 98
• Adoption, if required
• Not Adopted

MSC 99
• Approval
• Adoption, if required

MSC 100
• Approval
• Adoption, if required

2014

2015

2016

2017

2018

2019

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.
SUMMARY

• Capital costs for ship conversions much less than LNG and after treatment technologies with respect to marine applications

• New Build dual fuel tankers are only marginally more than for traditional fueled vessels and meet Tier III (NOx) requirements

• Methanol is already widely available and alleviates many infrastructure limitations for use as boiler fuel

• Methanol is one of the top 5 seaborne chemical commodities and has been safely handled for over 50 years

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