Methanol: An Emerging Marine Fuel

Methanol Institute -- October 2021
Singapore | Washington | Brussels | Beijing | Delhi
• The Methanol Institute (MI) was established in 1989
• Three decades later, MI is recognized as the trade association for the global methanol industry
• We facilitate methanol’s increased adoption from our Singapore headquarters and regional offices in Washington DC, Brussels, Beijing and Delhi
Essential Methanol

METHANOL PRODUCTION

COAL
NATURAL GAS
RENEWABLES/BIOMASS

DERIVATIVE CHEMICALS
Acetic Acid
Methyl Methacrylate (MMA)
Formaldehyde
Methanol

FUELS
Marine Fuel
Brazilian Biodiesel/Ethanol
Bio-Diesel Production
Dimethyl Ether (DME)

FINAL PRODUCTS

Formaldehyde 25%
Methyl terti-buty ether (MTBE) 11%
Methylamines 2%
Methanol-to-olefins 25%
Gasoline blending 14%
Biodiesel 3%
Dimethyl ether (DME) 3%
Others 4%
Acetic acid 8%
Methanol 1%
Methanol (methyl mercaptan) 1%

98 million tonnes

Source: Based on data from HMGI (2020)

www.methanol.org/join-us
Brown, Grey, Blue and Green

Figure 2. Principal methanol production routes

- **Biomass**
  - Gasification/reforming
  - Syngas
  - Green hydrogen (H₂)

- **Renewable electricity**
  - Electrolysis
  - Carbon capture and storage (CCS)
  - Syngas

- **Natural gas**
  - Reforming
  - Syngas

- **Coal**
  - Gasification
  - Syngas

**CO₂**
- **Renewable**
- **Non-renewable**

**CH₃OH**
- Green methanol
- Bio-methanol
- Bio-e-methanol
- E-methanol
- Grey methanol
- Brown methanol

Renewable CO₂ from bio-origin and through direct air capture (DAC)
Non-renewable CO₂ from fossil origin, industry

While there is not a standard colour code for the different types of methanol production processes, this illustration of various types of methanol according to feedstock and energy sources is an initial proposition that is meant to be a basis for further discussion with stakeholders.
Cost of Production

Figure 3. Current and future production costs of bio- and e-methanol

A carbon credit of USD 50/t CO₂ would lower renewable methanol production cost by about USD 80/t MeOH.

Notes: MeOH = methanol. Costs do not incorporate any carbon credit that might be available. Current fossil methanol cost and price are from coal and natural gas feedstock in 2020. Exchange rate used in this figure is USD 1 = EUR 0.9.
More & More Renewable Projects

https://www.methanol.org/renewable/
Why Use Methanol as a Marine Fuel?

What are the benefits of methanol as a marine fuel?

Isn’t methanol toxic? How to handle in case of a fire?

Does methanol reduce carbon emissions?

What do I need to do in case of a spill?

Is there enough methanol available?

How does methanol compare to other alternative fuels?

Is methanol globally available?

How much does methanol cost compared to fuel oil?

Is methanol IMO Tier III compliant?

How is methanol made?

Where can I bunker methanol?

What changes do I need to make to my vessel?
The Simplest of Alcohols

- Simple molecule rich in hydrogen, with only a single carbon bond
- Clear and colorless liquid at room temperature and ambient pressure
- Also known as “wood alcohol,” methanol can be produced from a wide range of feedstocks

Formula: CH₃OH
Density: 0.792 g.cm⁻³
Molar mass: 32.04 g mol⁻¹
Appearance: colourless liquid
The Methanol Molecule

- Methanol molecule is the same energy and chemical characteristics no matter how it is produced
- Completely fungible from grey to blue to green facilitating blending with reduced carbon intensity as low carbon and net carbon neutral supply grows
- Immediate benefits in reducing SOx, NOx, and PM
- Methanol runs well in existing engines with few modifications and significantly lower CAPEX when compared with other available alternative fuels
IMO 2050 GHG “levels of ambition”

- 2023 will be a critical year for IMO in determining their mid-term and long-term strategy on reduction of GHG emissions
- Energy-efficiency, logistics and speed reductions dominate mid-term tools (2023-2030)
- Fuels play an increasing role over 2030-2050 timeframe in meeting IMO GHG ambitions


DNV-GL 2050 Maritime Forecast assumes that a mixture of improved utilization and energy efficiencies, combined with a massive fuel decarbonization, will see IMO 2050 goal being met.

Shipping’s fuel mix in 2050 will have switched from being almost entirely oil dominated today, to a mix dominated by low- and/or net carbon neutral fuels (60%) and natural gas (30%, mostly LNG).

Fossil LNG gains a substantial share following the IMO ambitions. However, as regulations tighten in 2030 or 2040, depending on the decarbonization pathway, we see bio-LNG, e-LNG, bio-MGO and e-MGO used as drop-in fuel for existing ships, while bio-methanol, blue ammonia or e-ammonia are used for newbuilds and some retrofits.

In the Decarbonization by 2040 scenarios, instead of a transition via LNG, the fleet shifts directly to carbon-neutral methanol or ammonia, with bio-MGO and e-MGO as drop-in fuels for existing ships.

What is Potential Methanol Prize?

- The ammonia industry recently looked at DNV forecast and assumed ammonia would represent 25% of the maritime fuel mix by 2050, and if we assume methanol has similar share, we can speculate on the role of conventional versus green methanol:
  - Conventional methanol dominates from 2020-2030, with initial volumes of bio-methanol being blended.
  - From 2030-2040, conventional methanol begins to give way to increasing volumes of bio-methanol and e-methanol.
  - From 2040 onwards, e-methanol becomes one of the dominant marine fuels.
  - By 2050, methanol and ammonia each represent 25% of global bunker fuel, with methanol demand of 112.5 MMT/annual.

Assumption: 25% 2050 demand = 2.25 EJ (per DNV) = 112.5 MMT methanol, see similar calculation for ammonia, https://www.ammoniaenergy.org/articles/maritime-fuel-mix-could-be-25-ammonia-by-2050/
The Methanol Institute (MI) is calling on maritime policy-makers to adopt a ‘well-to-wake’ approach in GHG accounting of fuels to support the decarbonization of maritime transport. MI believes an approach that accounts for GHG emissions of the fuel’s entire value chain is essential to stimulate the uptake of renewable fuels that can drive the maritime industry’s energy transition.

https://www.methanol.org/marine/
Maersk: Methanol Game Changer

- 21 Feb 2021: Maersk announces that the world’s first carbon neutral container vessel by 2023 will operate on dual-fuel methanol
- Maersk has now ordered 2,100 TEU methanol duel-fueled feeder vessels from Korean shipyard
- 19 Aug 2021: Maersk secures 10,000 tons green e-methanol from Reintegrate in Denmark, using biogenic CO2 and solar power
- 24 Aug 2021: “Maersk accelerates fleet decarbonization with 8 large ocean-going vessels to operate on carbon neutral methanol”
  - More than half of Maersk’s 200 largest customers have carbon targets for their supply chains
  - 16,000 container (Twenty Foot Equivalent – TEU) vessels
  - Delivery in 2024, option for 4 additional vessels in 2025
  - $1.4 billion order each vessel $175 million 10-15% more expensive
  - Each ship will require 35,000-40,000 tons of methanol annually

“The reason that we have gone for methanol on the first one is that it is the most mature from the technology perspective; we can get an engine that can burn it.” Morten Bo Christiansen, head of decarbonization at Maersk

“That means that if we end up finding exactly the right solution then there will be a big retrofit opportunity for us.” Maersk CEO Soren Skou speaking during Maersk’s on 10 February earnings call

Methanol Fleet Growing Steadily

Maersk bets big on methanol with eight 16,000 teu ship order at HHI

AP Moller - Maersk is making a major commitment to methanol as future marine fuel with an order for eight 16,000 box dual-fuel containerships at Hyundai Heavy Industries (HHI).

Marcus Hant | Aug 24, 2021

When the eight 16,000 teu vessels are delivered from Q2 2024 they will enable Maersk to offer carbon neutral shipping to its customers on mainline trades - a first for the industry sector. The contract with HHI includes options for four additional vessels.

While many of Maersk’s competitors are opting for LNG as a low carbon, bridging fuel option, the Danish shipping company has taken the pledge to invest in carbon neutral based solutions from the outset.

Related: Maersk secures green e-methanol for world’s first carbon neutral container ship

OCI and more to come
On the Water

Engines Mature & Available

RETROFITS ECONOMICALLY VIABLE

METHANOL FUELED VESSELS AND PILOTS

100,000 Hours of Operations

www.methanol.org/join-us
More on the Way

- **Denmark:** Maersk orders one 2,100 teu methanol dual-fuel container ship, and 8 16,000 teu vessels with option for 4 additional methanol fueled ships
- **Sweden/Switzerland:** Proman Stena Bulk – joint venture of shipowner Stena Bulk and Proman Shipping a subsidiary of methanol producer Proman – to build now six 50,000 dwt tankers with methanol dual-fuel engines first deliveries 2022
- **Netherlands:** OCI NV, MAN, Eastern Pacific Shipping first methanol retrofit by 2023, newbuilds and retrofits
- **United States:** e1 Marine and Ardmore Shipping to deploy methanol-to-hydrogen generator and fuel cell system for propulsion and APU
- **Netherlands:** Damen Shipyards delivering first “methatug” to Port of Antwerp in 2022
- **Netherlands:** Damen Shipyards has developed new concept Offshore Support Vessel (OSV) to operate on methanol
- **Netherlands:** Van Oord has ordered self-elevating offshore installation vessel running on methanol
- **Ukraine:** Danube Shipping Company orders up to 33 river pushers using ABC ‘hybrid’ engines with methanol capability
- **Japan:** Sumitomo Heavy wins Approval in Principle from ClassNKK for methanol dual-fuel tanker
- **Germany:** Shipowner Liberty One has ordered new multipurpose (MPP) ship powered by methanol
- **Germany:** Shipowner SAL Heavy Lift to install FUELSAVE hydrogen/methanol injection system in 6 vessels
- **Germany:** Abeking & Rasmussen shipyard designing “green cruise” concept vessel using methanol fuel cells for hotel load and methanol propulsion engines
- **Germany:** AIDAnova will employ methanol fuel cells for propulsion under Pa-X-ell2 project
- **Germany:** Shipyard Fassmer has order from Alfred Wegener Institute to build methanol-powered research vessel UTHORN
- **Germany:** Port of Emden to receive new, methanol-powered harbor boat
- **Canada:** Naval architecture firm Robert Allan Ltd unveils methanol-fueled Raptor 2400 crew transfer vessel
Engines Offering Broadening

- **2015**
  - MAN Energy Solutions: LGI demonstration event at RCC-4190ME-X
  - Wärtsilä: Stena Line

- **2016**
  - MAN Energy Solutions: Test at MEF 7G80ME-C 893-34 LGM
  - Wärtsilä: Vessels

- **2017**
  - MAN Energy Solutions: Test at MHD 7G50ME-C 893-34 LGM
  - Wärtsilä: Vessels

- **2018**
  - MAN Energy Solutions: 1st sea trial on methanol MHD Farasah
  - Wärtsilä: Vessels

- **2019**
  - MAN Energy Solutions: Development of Tier III compliance by water in methanol
  - Wärtsilä: Order book of 14 LSH engines in total, 8 of series 6G 32D

- **2020**
  - MAN Energy Solutions:
  - Wärtsilä: Vessels

- **2021**
  - MAN Energy Solutions: LMG MHD Lindanger
  - Wärtsilä: Vessels

- **2022**
  - MAN Energy Solutions: NOx certification 6G80ME-C 115-Life 2020
  - Wärtsilä: Vessels

- **2023**
  - MAN Energy Solutions: Development of Tier III compliance by water in methanol
  - Wärtsilä: Vessels
Methanol Dual Fuel Standardized Design

- Methanol Fuel Service Tank
- Methanol Fuel Supply Room
- Cofferdam
- Methanol Storage Tank
Practical Fuel Storage

Source: Westfal-Larsen

Independent Tank

Integral Tank

Methane at -162° C

Methanol at ambient temperature

More space onboard required, even though higher energy density

More efficient use of space onboard, no impact on vessel range
Fuel Storage Volume Comparison

Energy per volume of tank system

[ MJ/l ]

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Temperature</th>
<th>Energy per volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diesel</td>
<td></td>
<td>40</td>
</tr>
<tr>
<td>Methanol</td>
<td>-162°C</td>
<td>15</td>
</tr>
<tr>
<td>LNG</td>
<td>-33°C</td>
<td>10</td>
</tr>
<tr>
<td>LNH3</td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>LOHC</td>
<td>-253°C</td>
<td>2</td>
</tr>
<tr>
<td>LH2</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Battery</td>
<td></td>
<td>0.2</td>
</tr>
</tbody>
</table>

*Based on marine, on-board storage

Source: Meyer Werft

Battery, H2, LOHC and LNH3 may not be suitable for long distances
Methanol Scalability

1 Vessel

20,000 tonnes of methanol

100 Vessels

2 million tonnes of methanol

2m tonnes of methanol

New Methanol Plant

Takes 2 years to build new ship, and 3 years to build new methanol plant
Green Maritime Methanol

- MI part of an industry consortium organized by TNO to study the use of (green) methanol in short sea shipping, a spin-off from the Horizon 2020 LeanShips project.

- TNO is an internationally renowned research institute with a great reputation for objective analysis.

- The GMM 1.0 study set the stage for a pilot with actual ships on the water with project partners (Horizon 2020 or other) under GMM 2.0.

- Focus is on renewable methanol but the technology, safety guidelines and policy can be used for conventional methanol too.

[https://greenmaritimemethanol.nl/](https://greenmaritimemethanol.nl/)
TNO: Potential Vessel Segments

- For Green Maritime Methanol program, TNO conducted assessment of market potential for Dutch/EU market for methanol as a marine fuel

- Heatmap of “methanol-applicability of shipping segments”

- Most shortsea and inland shipping markets appear feasible in terms of operational profiles, fuel consumption, and sailing patterns

- But important to recognize that the ocean-going vessels make of 20% of vessels and fully 80% of bunker demand

Source: TNO Report for GMM, Sept 2020
**Methanol engine retrofit solutions (WP1)**
Work Package 1 mission is to provide turnkey methanol conversion kits as a retrofit solution for high speed and medium speed diesel engines (200kW-4000kW).
[more](#)

**Harbour tug demo (WP2)**
Work Package 2 mission is the complete conversion of a harbour tug (owned by PoA) for methanol/MGO dual-fuel operation incl. set up of supply chain and training of crew.
[more](#)

**Coast guard vessel demo (WP4)**
Work Package 4 mission is to demonstrate methanol operation on board an ERRV (Emergency Recovery and Rescue Vessel) coast guard vessel, built by Super Toys.
[more](#)

**Pilot boat demo (WP3)**
Work Package 3 mission is to demonstrate methanol as a fuel for use in a smaller marine application for a longer period during true operational conditions.
[more](#)

**Methanol river cruise ship conversion concept (WP5)**
Work Package 5 mission is to develop the conversion concept for a River Cruise Ship for a fuel change from diesel to a methanol-driven propulsion system.
[more](#)

**Next generation methanol engines (WP6)**
Work Package 6 mission is to develop the next generation of methanol engines, that fully exploit methanol's beneficial properties as an engine fuel, for increased efficiency and even lower emissions.
[more](#)
Currently:
- Reviewing final draft
- Circulated to MFC for feedback
- Planned Jul/Aug for formal release

Targeted outcome is to
- obtain MSA endorsement
- allow CCS to begin to class methanol-fueled vessels
- create bunkering hubs
- begin to develop standardized methanol designed vessels

WTRI – China & Singapore

China
- China Waterborne Transport Research Institute (under Ministry of Transport) proposed study to provide a roadmap for the adoption of methanol as a marine fuel for China
- Techno-Economic Assessment; Policy analysis/recommendations
- China annually consumes 20-30 MMT of bunker fuel
- There are 630,000 vessels operating in China's coastal regions (including fishing fleet) and inland waterways (140,000 vessels)
- In terms of potential methanol demand, marine applications have the potential to be no less in size than the China market for boilers or cook stoves, or conservatively in the low single digits, in millions of tons demand, over the next five years
- Total Budget = USD$140,000, with MI as USD$50,000 sponsor, other sponsors Methanex, Sinopec, Shanghai Huayi Group

Singapore
- Singapore’s Maritime Institute and MPA recently instructed the Marine Energy Test Bed Department of NTU to engage WTRI in a similar study as MI engaged WTRI
- Study to commence in September with MI participation
- Study will assess feasibility of methanol fuelled vessels in China and Singapore in line with MPA’s Roadmap 2030
IMO IGF Code Methanol Approval

CCC 1
- Ethyl/methyl alcohol
- Fuel cells
- Low-flashpoint diesel

CCC 2
- Ethyl/methyl alcohol
- Fuel cells
- Low-flashpoint diesel

CCC 3
- Fuel cells
- Ethyl/methyl alcohol
- Low-flashpoint diesel

CCC 4
- Fuel cells
- Ethyl/methyl alcohol
- Low-flashpoint diesel

MSC 101
- Amendments
- Referral to other sub-committees

MSC 102
- Amendments
- Approval
- Adoption

Draft Interim Guidelines Validated

MSC 100
- Amendments
- Confirmation
- Referral to other sub-committees
Methanol Trading Hubs
Available and Easily Bunkered
Methanol Barge Bunkering

- 300mt stem successfully delivered May 2021
- Stem placed per LR/MI Methanol Bunkering TR
- Partners included:
  - Methanex
  - Port of Rotterdam
  - Vopak
  - NYK
  - TankMatch

- Require more such demonstrations at leading ports
- Will support pilots and general uptake of methanol
- Ports of interest:
  - Antwerp, Rotterdam
  - Zhoushan, Ningbo
  - Singapore
  - Panama
  - Others
Methanol Pricing

Argus: existing and upcoming price assessments

<table>
<thead>
<tr>
<th>Overview</th>
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<tbody>
<tr>
<td>Price assessment</td>
</tr>
<tr>
<td>LNG bunkering</td>
</tr>
<tr>
<td>CO2</td>
</tr>
<tr>
<td>Grey ammonia</td>
</tr>
<tr>
<td>Green ammonia</td>
</tr>
<tr>
<td>FAME biofuel</td>
</tr>
<tr>
<td>Green methanol, bio LNG</td>
</tr>
<tr>
<td>Biodiesel B5, B10, B20</td>
</tr>
</tbody>
</table>

European Commodity Price Comparison

Maersk estimate that a doubling of fuel costs would only add 6c to the price of $100 trainers

Moersk Sustainability Report 2020
Main Risks of Methanol as a Fuel 1 of 2

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

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

- Low flash point

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

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

- Corrosive

- Main risks of methanol on ships
## Main Risks of Methanol as a Fuel 2 of 2

<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>
## Hazard Comparison

<table>
<thead>
<tr>
<th>Hazard pictograms (CPL)</th>
<th>METHANOL</th>
<th>DIESEL</th>
<th>GASOLINE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><img src="image" alt="Methanol Pictogram" /></td>
<td><img src="image" alt="Diesel Pictogram" /></td>
<td><img src="image" alt="Gasoline Pictogram" /></td>
</tr>
</tbody>
</table>

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

### Hazard statements (CPL)
- **Methanol**
  - MSDS: 1. Provide a balanced view of performance and environmental impact.
  - GHS: Globally harmonized system of classification and labeling.

- **Diesel**
  - GHS: Globally harmonized system of classification and labeling.

- **Gasoline**
  - GHS: Globally harmonized system of classification and labeling.

### Precautionary statements (CLP)

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Methanol classified as “not more dangerous” than other fuels such as gasoline or diesel – fuels largely familiar to most people
Improving Local Air Quality

Emission reduction potential:

- $\text{SO}_x$: >99%
  - Source: Stena Line
- PM: >95%
  - Source: Stena Line
- $\text{NO}_x$: >80%
  - Source: Stena Line

Graph showing emission reduction potential:
- NOx [g/kWh] vs. Load [%]
- Graphs for Diesel, Methanol, and Methanol + water.
- Source: MAN ES
Significant CO₂ Reduction Potential

Source: https://sustainablepower.application.marin.nl
Oil Spills Still Happen….
Pollution in Perspective

Methanol \(^5\) 15,400 mg/l

- Methanol is a more environmentally-benign fuel in marine environments
- In a waterbody, nearly 200 times more methanol is needed to kill half the number of fish than marine heavy fuel oil

**LC 50: Lethal Dose: Fish**

<table>
<thead>
<tr>
<th>Fuel</th>
<th>LC 50 (mg/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gasoline</td>
<td>8.2</td>
</tr>
<tr>
<td>Methane</td>
<td>49.9</td>
</tr>
<tr>
<td>Diesel</td>
<td>65</td>
</tr>
<tr>
<td>Heavy Fuel Oil</td>
<td>79</td>
</tr>
<tr>
<td>Ammonia</td>
<td>0.068</td>
</tr>
</tbody>
</table>

Sources:
1. Petrobras/Statoll ASA, Safety Data Sheet, ECHA registration dossier Gasoline
2. ECHA, European Chemicals Agency, registration dossier Methane
3. ECHA, European Chemicals Agency, registration dossier Diesel
4. GKG/ A/S Dansk Shell, Safety Data Sheet
5. ECHA, European Chemicals Agency, registration dossier Methanol
6. ECHA, European Chemicals Agency, registration dossier Ammonia

www.methanol.org/join-us
# Spill & Salvage Economic Impact

## 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><strong>Ship</strong></td>
<td>Erika</td>
<td>Tanio</td>
<td>-</td>
</tr>
<tr>
<td><strong>Fuel</strong></td>
<td>Heavy Fuel Oil</td>
<td>Heavy Fuel Oil</td>
<td>Methanol</td>
</tr>
<tr>
<td>Released amount</td>
<td>19000 t</td>
<td>13500 t</td>
<td>10000 t</td>
</tr>
<tr>
<td>Affected coastline</td>
<td>400km</td>
<td>200km</td>
<td>0km</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>

### MeOH spill simulations

1. **Simulation 1**: Release of 10,000 tons Methanol at open sea. Concentration of 0.36% after 1 hour.
2. **Simulation 2**: Release of 10,000 l/h from a coastal pier. Concentration of 0.36% after 1 hour, Concentration of 0.13% after 3 hours.

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


- Less toxic than gasoline or diesel
- Methanol poisoning is not carcinogenic and requires simple treatment
- No additional GHG potential (methane slip)
- Miscible in water – large spill concentration will rapidly decrease with only very short-term effects
- Far less hazardous to the environment
- Methanol is fully miscible with water and dissolves readily
- It is biodegradable and does not bioaccumulate
- Methanol is not rated as toxic to aquatic organisms using the GESAMP rating system (Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection) (acute and chronic toxicity measures)
Timeline for expected availability of alternative fuel technologies – our best estimate for when these may be available for onboard use

**Ammonia**
- ICE
- Fuel cell

**Hydrogen**
- ICE
- Fuel cell

**Methanol**
- ICE
- Fuel cell

Key: [Internal combustion engine (ICE)]

©DNV 2021
### Total cost of ownership (M€/yr). Base case.

Ship category: large ferries.
Three different utilization rates: short, medium, long distance.

Costs include: fuel production, fuel infrastructure, amnuitized investments in propulsion technologies, energy storage and reduced income due to less cargo space.

The colour coding is within each fuel category and utilisation rate to highlight the cheapest option.

MGO and BE are coloured differently but are comparable in terms of costs to all other cases in the ship travel category.

**Methanol shows lowest cost within all fuel categories.**

**The three methanol production options**

<table>
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</table>
**Methanol vs Ammonia**

**Ammonia** – Converting Ammonia to Hydrogen requires higher heat (600C to 900C = Outside Heat Source), more expensive equipment, and large centralized facilities for Hydrogen distribution to end users. Public spaces cannot currently convert Ammonia to Hydrogen without high costs and/or public safety risk.

>50% of Hydrogen’s Cost Occurs After Hydrogen Leaves The Production Facility.

**Methanol** – Methanol can convert to Hydrogen at lower temperatures (300C to 450C). Methanol also leverages existing liquids infrastructure and converts to Hydrogen with proven technology that is less expensive, safer, and with a limited footprint.

Source: Webber Research and Advisory
Methanol Marine SWOT

**STRENGTHS**
- Available compliant liquid
- New build & retrofit
- Safe handling experience
- Sustainable pathways
- Engine/infrastructure availability

**WEAKNESSES**
- Energy density
- Alt fuel understanding
- Limited RM availability

**OPPORTUNITIES**
- Efficient logistics | design
- Trading | price competitive
- Feedstock flexibility | blend

**THREATS**
- Delay of GHG policy
- Continued low oil price
- Space on-board

**FULLY COMPLIANT FUEL, READILY AVAILABLE, COMPETITIVE ON BOTH CAPEX AND OPEX CRITERIA, WITH A RANGE OF FUTURE PROOF PATHWAYS**
<table>
<thead>
<tr>
<th>Our Conclusions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increasing number of vessels</td>
</tr>
<tr>
<td>More OEM’s offering engines</td>
</tr>
<tr>
<td>Liquid at atmospheric pressure</td>
</tr>
<tr>
<td>Very low emissions</td>
</tr>
<tr>
<td>Environmentally friendly</td>
</tr>
<tr>
<td>Broad range of sustainable feedstocks</td>
</tr>
<tr>
<td>Cost competitive</td>
</tr>
<tr>
<td>Available in most major ports</td>
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<tr>
<td>Future proof</td>
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</table>
Our Contacts

Eelco Dekker
Chief EU Representative
edekker@methanol.org

Matthias Olafsson
Manager of Government & Public Affairs - Europe
molafsson@methanol.org

Greg Dolan
CEO
gdolan@methanol.org

Larry Navin
Director of Government and Public Affairs Americas / Europe Operations
lnavin@methanol.org

London Douglas
Social Media and Web Manager
ldouglas@methanol.org

Prakriti Sethi
India Representative
psethi@methanol.org

Zhao Kai
Chief China Representative
kzhao@methanol.org

Chris Chatterton
COO
cchatterton@methanol.org

Tim Chan
Assistant Director of Government & Public Affairs (AP/ME)
tchan@methanol.org

Belinda Pun
Executive Manager
bpunr@methanol.org

Matthias Olafsson
Manager of Government & Public Affairs - Europe
molafsson@methanol.org

Eelco Dekker
Chief EU Representative
edekker@methanol.org

Chris Chatterton
COO
cchatterton@methanol.org

Tim Chan
Assistant Director of Government & Public Affairs (AP/ME)
tchan@methanol.org

Belinda Pun
Executive Manager
bpunr@methanol.org

Prakriti Sethi
India Representative
psethi@methanol.org

Zhao Kai
Chief China Representative
kzhao@methanol.org

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