SUSTAINABILITY WHITEPAPER

# METHANOL AS MARINE FUEL

FEBRUARY 2021

ABS

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# OVERVIEW

## OBJECTIVE

The maritime industry faces challenges in adopting new technologies and operational practices to comply with increasingly strict international, national, and local regulations aimed at reducing Sulfur Oxides (SOx), Nitrogen Oxides (NOx), Particulate Matter (PM), Carbon and Greenhouse Gas (GHG) emissions from ships. The regulations introduced by the International Maritime Organization (IMO), the European Union, the United States Environmental Protection Agency, the California Air Resources Board, and others are designed to reduce these emissions from ships.
Many approaches are being considered to reduce carbon emissions in shipping. The American Bureau of Shipping (ABS) publication Setting the Course to Low Carbon Shipping: Pathways to Sustainable Shipping, referred to as 'Outlook II' in this document, has categorized the available maritime fuel options for decarbonization.

Through a series of sustainability whitepaper publications, ABS focuses on individually detailing certain decarbonization fuel options and technologies. This whitepaper provides information for the consideration of methanol as a marine fuel.

## INTRODUCTION

Methanol also called methyl alcohol or wood alcohol is available worldwide and has been used in a variety of applications for many decades. It is most commonly produced on a commercial scale from natural gas, but it can also be produced from renewable sources such as biomass or electrolysis powered by renewable power and supported with carbon capture utilization technology. Either production pathway blended into conventional methanol in increasing volumes could considerably reduce the carbon dioxide ($CO_2$) footprint of its use as fuel. Due to its potential to reduce the $CO_2$ output from marine fuels, applications of methanol are drawing a wider interest from owners of oceangoing vessels, short sea shippers, ferries, cruises, and inland waterway vessels.

Methanol is a colorless liquid at ambient temperature and pressure with a characteristic pungent odor. It is easier to store and handle than liquefied natural gas (LNG), ammonia ($NH_3$), and hydrogen fuels. There are also fewer challenges in adopting methanol as marine fuel compared to LNG or hydrogen. Methanol has the highest hydrogen-to-carbon ratio of any liquid fuel, a relationship that potentially lowers the $CO_2$ emissions from combustion when compared to conventional fuel oils. From an environmental perspective, methanol is readily biodegradable in both aerobic and aquatic environments. With a half-life in surface water of one to seven days, there is less impact on the marine environment if a leak or spill occurs.

Methanol's specific energy of 19,700 kJ/kg is much lower than that of LNG and conventional liquid fuels. For the same energy content, methanol requires about 2.54 times more storage volume than conventional fuels. When comparing methanol to LNG, an overall decrease in the effective volumetric density of LNG is to be accounted for due to packaging factors for cylindrical tanks, insulation and filling factors, boil-off gas, and custody transfer losses.

## METHANOL AS FUEL FOR REDUCTION OF GREENHOUSE GAS

To assess the environmental impact of methanol as a marine fuel, it is critical to consider the emissions from its production process. Figure 1 shows a graphical representation of a life-cycle analysis (LCA) of fuels, which includes emissions from extraction of the raw material, fuel production, transportation and storage, bunkering, and finally, from combustion on board the vessel.

Fuel production pathways that are energy and carbon-intensive may not be attractive in the future and may increase the price of fuel due to proposed carbon levies. Carbon-intensive production methods also may be restricted by new regulations.

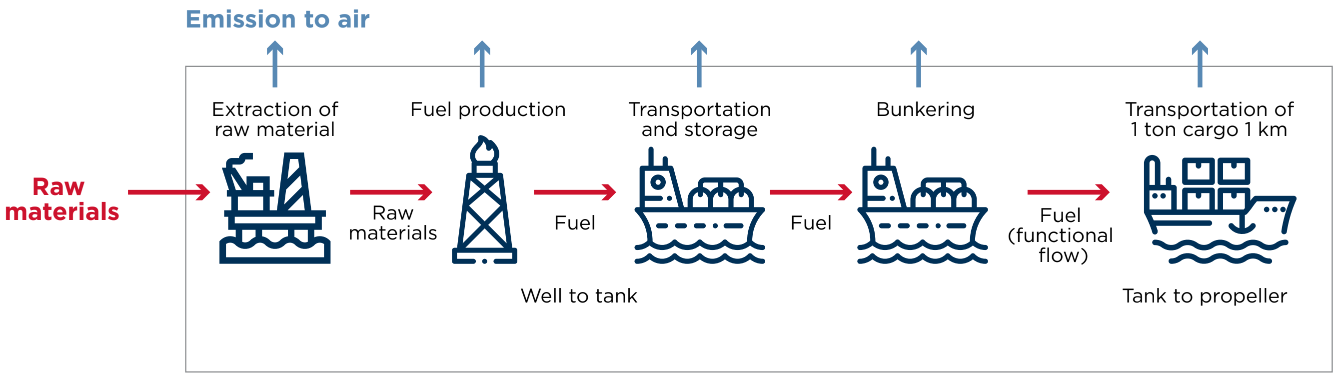



*Figure 1: Life cycle analysis of marine fuels from well to propeller*

Raw material as feedstock plays an important role in the reduction of life cycle GHG emissions. There are various feedstocks used to produce methanol, and natural gas is one of the most common feedstock. This production process, which is energy-intensive, combines reforming and converting in three steps: synthesis gas (syngas) preparation; methanol synthesis; and methanol purification/distillation. With steam added, natural gas is reformed by partial oxidization to syngas including carbon monoxide (CO), $CO_2$, and hydrogen.

The syngas is then converted to methanol with by-products of hydrogen and water. The distillation step removes the water by separating the methanol through reboiling. Depending on the specified water content of the methanol, it may be possible to simplify methanol production at this step. Reboiler heat can be obtained by cooling the syngas. The process will generate excessive heat that can be used for generating electricity. Therefore, the process can make use of the self-generated heat, and no extra energy input is needed for the plant.

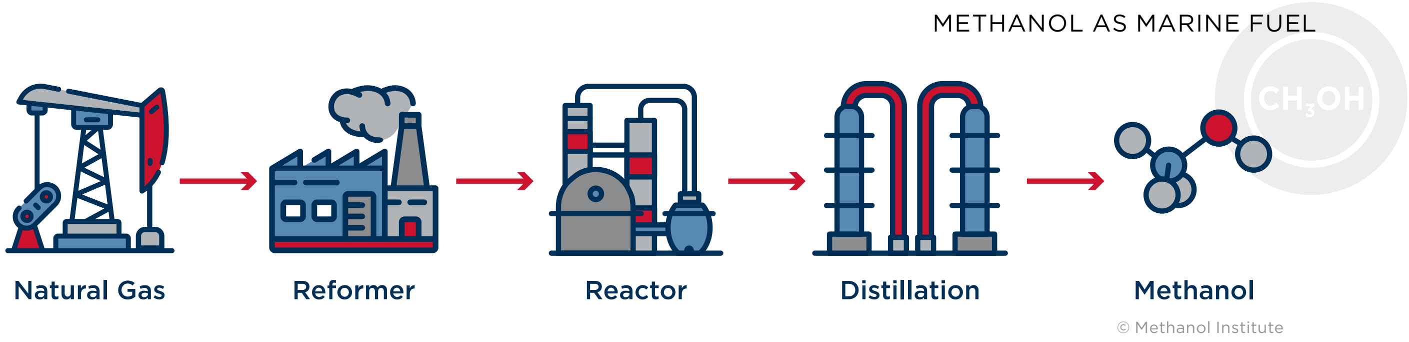
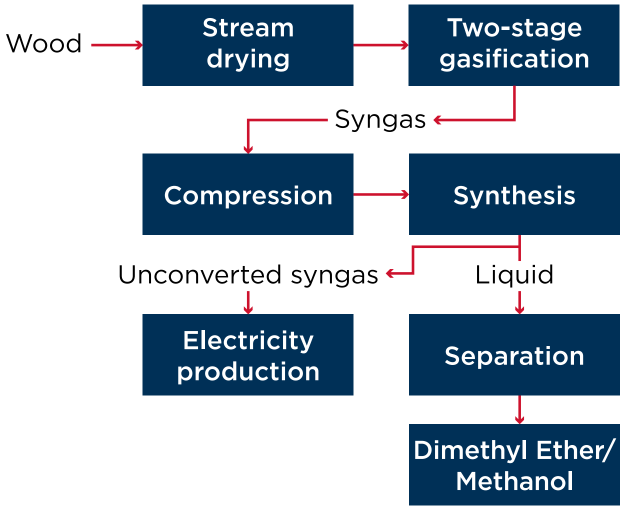



*Figure 2: Methanol production from natural gas*

The GHG emissions from the production of methanol from natural gas is known as well-to-tank emissions. When natural gas is used as feedstock, the GHG emissions from well-to-tank are higher, which implies that well-to-propeller emissions are slightly higher than conventional fuels.

Biomass, such as wood, municipal solid waste, and sewage sludge as well as biogas from landfills and wastewater treatment can be used as feedstock. Methanol produced with such feedstocks is considered as bio-methanol. The process is similar to that of using natural gas as feedstock; syngas is formed when the feedstock is subjected to a specific temperature and pressure. Production of methanol from biomass or biogas is seen as a GHG-neutral process (the amount of carbon released is roughly equal to the carbon absorbed by the plant matter during its lifetime), but emissions may be produced when generating energy for the process.




https://www.researchgate.net/publication/316772405_Progress_in_biofuel_production_from_gasification

*Figure 3: Biomass (Wood) to methanol process*

In such production processes, the emissions come from the power generation equipment used to create the energy needed. The source of energy is an important factor impacting the life cycle GHG emissions. Using renewable energy for production would further reduce the GHG of bio-methanol. Using coal as feedstock for methanol production is employed commercially in China, but it does have a negative impact on GHG emissions.

In addition to fossil and biomass sources, low-carbon methanol can be produced by carbon dioxide recovery (CDR), a technique that converts excess $CO_2$ from syngas generated from steam methane reforming to produce additional methanol. CDR has been developed by Mitsubishi Heavy Industries (MHI) and used by the Gulf Petrochemical Industries Company in Bahrain and the Qatar Fuel Additives Company in Qatar. The Azerbaijan Methanol Company in Baku and the South Louisiana Methanol facility also are using CDR for additional methanol production. Additionally, the carbon footprint of a natural gas-based methanol plant can be further reduced with the addition of renewable electricity (solar, wind, geothermal, hydropower, etc.) to replace some of the process energy consumption.

The clean-burning properties of methanol provide a significant reduction in SOx and PM emissions as the methanol molecule ($CH_3OH$) has no sulfur and no carbon-to-carbon bonds that create particulate matter. Methanol also has a lower adiabatic flame temperature than diesel, which can reduce the peak cylinder temperature and limit NOx formation during combustion. To reach IMO Tier III emission levels, aftertreatment systems may be necessary when using methanol as a marine fuel. However, recent studies by MAN Energy Solutions (MAN) have used the addition of water to methanol in order to control NOx formation during combustion. The results showed that adding water can help the engine to meet the Tier III NOx regulations without the use of EGR or SCR.

Industry studies indicate that life-cycle NOx and SOx emissions for methanol are about 45 percent and 8 percent of conventional fuels per unit energy and according to the IMO; its GHG emission performance will depend on the feedstock and source of energy used for production.


## METHANOL AS MARINE FUEL

Methanol's uptake and application as a marine fuel is only beginning as it was only approved for inclusion in the IMO's Interim Guidelines for Low Flash Point Fuels in November 2020. Methanol may be used onboard ships as fuel for internal combustion engines or as a fuel source for fuel cell operation.

MAN has developed the 'ME-LGI' concept for high-pressure injection of liquid low flashpoint fuels such as methanol. This involves a relatively low fuel supply pressure, and all high-pressure pumping is done within the injector. Fuel injection is accomplished by a booster fuel injection valve that raises the injection pressure to 550-600 bar. The first application of this concept was in methanol-burning Dual Fuel (DF) engines on several methanol carriers.

Methanol is a widely shipped commodity and used in a variety of applications such as the chemical industry for many decades. The supply chains already exist and are well-positioned to reliably supply methanol as a marine fuel in many ports around the world. As methanol is a liquid at ambient temperature, the existing liquid fuel infrastructure may also be leveraged for the supply of methanol with limited conversion. Bunker vessels may also be a viable option for maritime bunkering.

Onboard containment of methanol is easier than LNG. As a liquid fuel, only minor modifications are needed to existing systems/infrastructure used for conventional marine fuels. The modifications are mainly concerning the low flash point of methanol. Major safety considerations include:

- Methanol tank location
- Methanol protection
- Inerting and venting of a methanol tank
- Spill containment
- Vapor and fire detection
- Fire fighting

For the two-stroke ME-LGIM system from MAN, the methanol fuel supply system to the engines is significantly simpler compared to LNG as fuel without the need for cryogenic storage and handling. The fuel supply to the engine can be accomplished using a low-pressure system, e.g., 10 bar. The similarity to LNG as fuel is the safety consideration as methanol has a low flashpoint.

Wartsila has also developed a retrofit conversion for engines onboard the Stena Germanica RoPax ferry. This is a variant of the Wartsila HP DF engine technology.

# METHANOL SAFETY

## CHARACTERISTICS OF METHANOL

Table 1 lists the key properties of methanol. Methanol is a clear liquid compound with the chemical formula $CH_3OH$. Methanol has a low flashpoint and is corrosive to certain materials.

Methanol is toxic and poisonous to the central nervous system which may cause blindness, coma, and death if ingested in large quantities. Since its vapor is heavier than air, it increases the risk of inhaling the vapor by the onboard crew. Methanol, being a toxic substance, is to be handled carefully if spilled or leaked in confined spaces or on deck. At high vapor concentrations, methanol can also cause asphyxiation.

The United States National Institute for Occupational Safety and Health (NIOSH) Immediately Dangerous to Life or Health Concentrations (IDLH) value is 6,000 ppm. The Occupational Safety and Health Administration (OSHA) Permissible Exposure Limit is 200 ppm time-weighted average (TWA).

Methanol vapor tends to accumulate at low points, e.g., the bottom of tanks or low pipe points. Therefore, special attention needs to be given to the placement of ventilation and detection arrangements in spaces where methanol leakage
may occur.

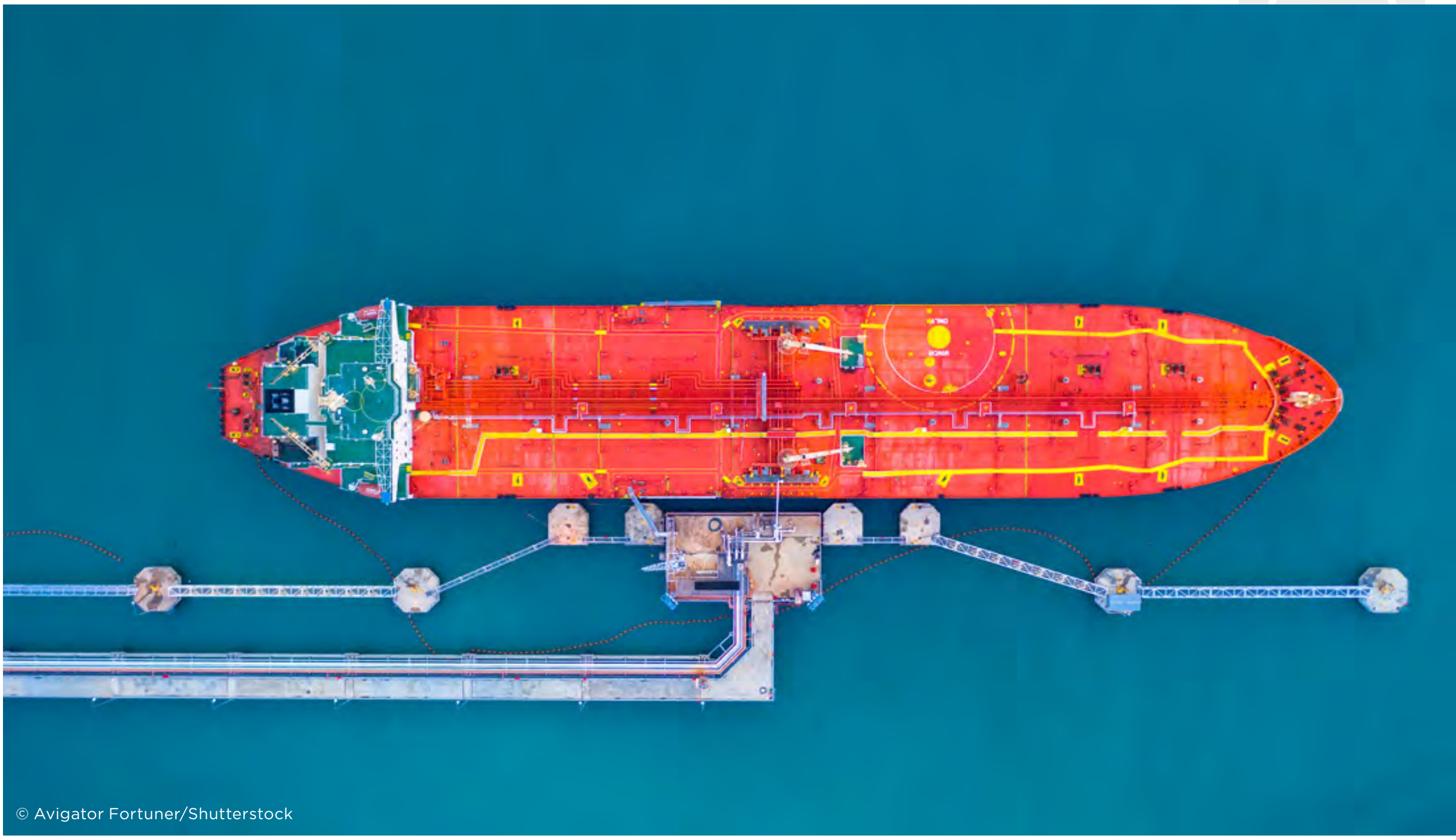
| METHANOL PROPERTY | VALUE |
|---|---|
| Energy density (MJ/L) | 15.7 |
| Heat of vaporization (kJ/kg) | 1098 |
| Autoignition temperature (°C) | 450 |
| Liquid density (kg/m3) | 798 |
| Adiabatic flame temperature at 1 bar (°C) | 1980 |
| Molecular weight (g/mol) | 32.04 |
| Melting point (°C) | -97.8 |
| Boiling point at 1 bar (°C) | 65 |
| Critical temperature (°C) | 239.4 |
| Critical pressure (bar) | 80.48 |
| Flammable range in dry air (%) | 6 – 36.5 |
| Cetane number | < 5 |
| Octane number | 109 |
| Flash point (°C) | 12 |
| Heavy Fuel Oil (HFO) equivalent volume | 2.54 |

*Table 1: Properties of methanol*


Methanol flames are particularly hazardous, as they burn at low temperatures with a flame that is nearly invisible in daylight with no smoke. A methanol flame often goes undetected until it has spread to adjacent materials that burn in a wider range of light.

The flammable range of methanol vapor to air is between 6% and 36.5% and can create an explosive or flammable environment. A methanol-water mixture of at least 25% methanol is still capable of burning, so special fire extinguishing practices are to be followed, including the use of alcohol-resistant foams.

The corrosive properties of methanol with certain materials means that special consideration is to be given to the tank coatings, pipes, and piping fixtures within the fuel handling system.



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## TOXICITY

### ENVIRONMENTAL EFFECT

Methanol has significantly less impact if spilled or leaked into the environment than conventional hydrocarbon fuels. Methanol dissolves readily in water, and only very high concentrations in the environment create lethal conditions or any changing effect on the local marine life. This means that a methanol spill would result in limited damage to the environment except for the release of carbon into the marine ecosystem. Methanol in the ocean is common, produced naturally by phytoplankton, and is readily consumed by bacteria microbes, thus entering, and supporting the food chain.

### TOXICITY TO HUMANS

When carried as cargo, the International Bulk Chemical Code (IBC Code) does not classify methanol as a toxic substance. When used in systems onboard, however, most Safety Data Sheets (SDS) categorize liquid methanol as a toxic chemical.

Exposure to liquid methanol on the skin can cause irritation, dryness, cracking, inflammation, or burns. Methanol in the human body (either ingested or skin absorption) oxidizes and produces formic acid and formaldehyde. A minimum of 10 mL of pure methanol ingested can accumulate dangerous levels of formic acid and destroy the optical nerves, causing blurry or indistinct vision, changes in color perception, and eventual blindness. Other symptoms include headache, vertigo, weakness, nausea, vomiting, or inebriation, and overexposure will lead to death, where the median ingested lethal dose is approximately 100 mL.

Allowable occupational exposure limits to methanol may vary by country. A widely used value based on the Methanex Safety Data Sheet is 200 ppm (260 mg/m3) TWA for exposure to the skin. Higher values are given for short-term exposure limits alternatively to long-term low exposure amounts.

The handling of methanol is to be carried out carefully as it contrasts with conventional marine fuels by its high toxicity and danger to humans. Crews are to be properly trained and be aware of the additional hazards and characteristics of methanol, including in the case of leaks, spills, or exposure. The Interim Guidelines for the Safety of Ships using Methyl/Ethyl Alcohol as Fuel (MSC.1/Circ.1621) provide guidelines for crew safety.

In the case of a methanol spill, appropriate response equipment is to be available, including:

- Adequate amounts of sorbent materials and plastic (non-sparking) shovel to disperse materials
- Caution tape or other barrier types to isolate the spill area
- Drum or container to hold the collected waste material
- Emergency communication devices

Proper personal protective equipment for responders when handling methanol may include, but is not limited to:

- Chemical splash goggles and face shields
- Butyl or nitrile gloves
- Anti-static rubber gloves
- Chemical-resistant coveralls
- Provision for supplied fresh breathing air
- Multiple fire extinguishers
- Industrial first aid kits
- Water showers and eyewash stations
- Supply of potable water for washing and drinking


### CORROSION

Methanol is corrosive to certain materials, and the use of methanol as a marine fuel may require the redesign of some combustion engine parts. Corrosion-inhibiting additives or special coatings could also be an option to reduce methanol corrosion.

The conductivity of methanol increases its corrosiveness in the presence of certain metallic materials such as aluminum and titanium alloys. These materials are commonly used in natural gas and distillate fuel systems but may not be used for pipes or fittings intended for methanol fuel or methanol fuel blends.

Storage tanks holding methanol are to have an appropriate grade of stainless steel or methanol-resistant coating to the tank interior. If coatings are used, it is important to consider that any acidic impurities can damage the coating material, and these damages are to be addressed quickly before accelerated corrosion occurs, including pitting, iron pick-up, and further methanol contamination.

Non-metallic materials used in fuel tanks and pipes are to consist of appropriate methanol-compatible materials, such as nylon, neoprene, or non-butyl rubber.

## FIRE SAFETY

### FIRE PREVENTION AND DETECTION

The Interim Guidelines for the Safety of Ships using Methyl/Ethyl Alcohol as fuel (MSC.1/Circ.1621) and the Methanol Institute Safe Handling Guide give provisions for methanol fire detection and firefighting techniques.

Methanol as a liquid does not vaporize rapidly at ambient temperature and pressure as a liquefied gas would. However, methanol vapor in concentrations between 6-36.5% of air is flammable when introduced to an ignition source.

Any methanol manifold, ventilation, or pressure/vacuum (P/V) relief valve is to have an appropriate clear adjacent area to avoid the introduction of ignition sources or sparks.

The autoignition temperature of methanol gas is 450°C, a temperature that requires electrical equipment to be assigned a T2 surface temperature class.

To protect methanol tank vapor space from explosive behavior, inert gas can be used. In addition to the risk of explosion, carbon dioxide in the presence of methanol and moist or salty conditions can create corrosive conditions. Therefore, inert gases that contain carbon dioxide are to be avoided, and nitrogen gas is to be used to blanket methanol.

Methanol is known for burning with a low-light and low-temperature flame, and therefore flame detection if burning pure can be especially difficult. Flame detection equipment such as infrared (IR) cameras, foam extinguishing systems, and robust operational procedures are to be in place to protect against methanol fires. Methanol flames do not produce smoke or soot, so a smoke detector will not likely be an effective source of fire detection. Heat detector type fire detection systems may also be unreliable for methanol due to the flame's low temperature.

Flame detectors with infrared light detection are ideal for detecting methanol flame. Soot particles in typical fire smoke tend to absorb electromagnetic radiation from carbon dioxide. However, as there is no soot from methanol flames, carbon dioxide radiation is more significant, and the flame is easily detected in the infrared light region. Some flame detectors only alarm when light from both the ultraviolet (UV) and IR regions are detected, but these are not to be used for methanol flame detection.

Vapor detection can also be used simultaneously for leak and fire detection by monitoring oxygen and carbon dioxide levels. Closed-circuit television (CCTV) can also help with fire detection, and infrared cameras used in conjunction with CCTV could be used for methanol flame detection, but these may incur added expenses beyond what is minimally necessary.

Protection against leaks adjacent to methanol tanks or pipes are to include gas detection systems near expected leak points, as well as positions both near the ceiling as well as in surrounding low points. Alarms for gas detection are to be sensitive enough to alarm well before the concentration levels reach toxic or flammable levels.

Tank overflow and leak protection are to be adequate for the holding arrangement in place to prevent flammable conditions in areas with potential ignition sources. In some cases, additional safety measures for cofferdams are to be in place to prevent a potentially dangerous buildup of methanol liquid or vapor.

### FIRE FIGHTING

Flammable vapors burn over a methanol pool, and the liquid evaporates due to the heat, contributing to the burn. Therefore, the most effective ways of fighting a methanol fire are to smother the vapors or to dilute the flammable substances below their lower flammable limit.

Portable dry chemical or $CO_2$ extinguishers can be used for small methanol fires where there is less risk of methanol pool evaporation. For larger volumes of methanol, water extinguishers may be used, if the volume of water is at least four times the size of the methanol pool. Alcohol Resistant Film Forming Foam (AR-FFF) extinguishers with foam-water proportioning equipment are a highly recommended method for large methanol pool fires, such as a potential fire below methanol fuel tanks.

# REGULATORY COMPLIANCE CONSIDERATIONS

## INTERNATIONAL STANDARDS

Several International Organization for Standardization (ISO) standards and technical specifications have been developed to support the application of LNG and other low-flashpoint fuels to the marine sector. The IMO Maritime Safety Committee (MSC) has also now adopted MSC.1/Circ.1621, the Interim Guidelines for the Safety of Ships using Methyl/Ethyl Alcohol as fuel.

Furthermore, to support the uptake of methanol and ethanol as marine fuels, at the 99th session of the IMO MSC meeting, held May 16-25, 2018, the IMO invited the ISO to develop standards for methyl/ethyl alcohol as a fuel and methyl/ethyl alcohol fuel couplings. Some concerns on lack of sufficient experience as a marine fuel were expressed; however, the ISO is willing to develop such standards, hence development is expected in this regard.


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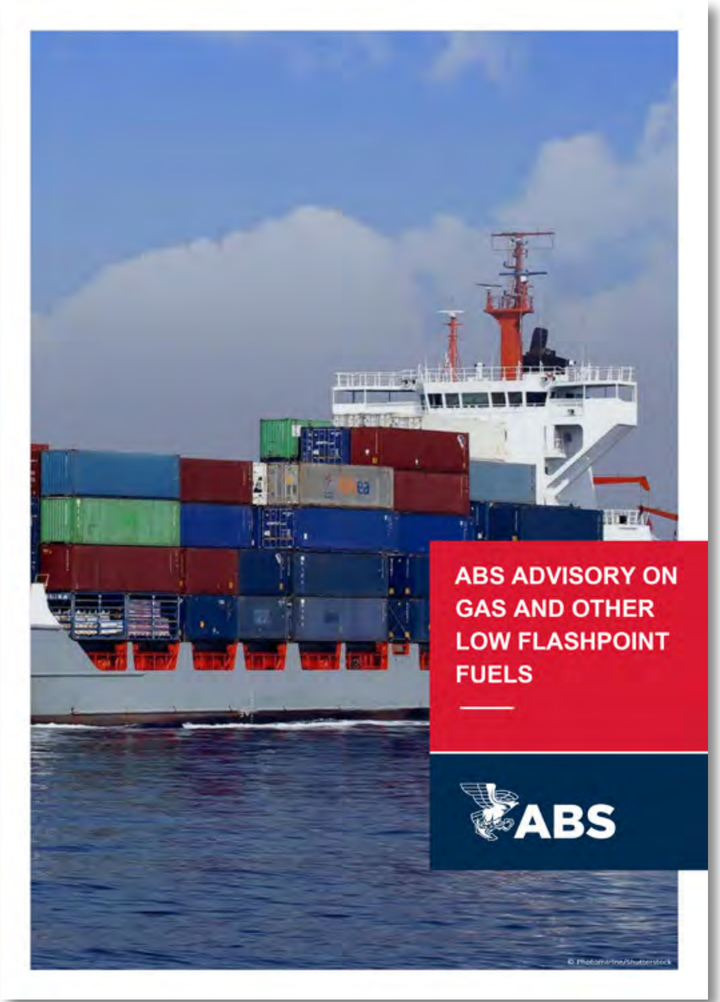
## ABS RULES AND GUIDES

ABS has two IMO safety codes related to the carriage and use of natural gas and other low- flashpoint fuels embedded directly in the Rules. The International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (IGC Code) is incorporated under Part 5C-8 of the ABS *Rules for Building and Classing Marine Vessels* (MVR) for specific vessel types, Vessels Intended to Carry Liquefied Gases in Bulk, and the International Code of Safety for Ships Using Gases or other Low-Flashpoint Fuels (IGF Code) under part 5C-13 for Vessels Using Gases or other Low-Flashpoint Fuels.

Both 5C-8 and 5C-13 of the Rules also incorporate additional ABS requirements and interpretations, together with applicable International Association of Classification Societies (IACS) unified requirements and unified interpretations. The text of the statutory codes is shown in italics to differentiate between the statutory code text and additional ABS or IACS text.




Through the ABS *Guide for Gas and Other Low-Flashpoint Fuel Ready Vessels,* ABS offers alternative fuel ready notations including the 'Methanol Fuel Ready' notation. This Guide is to be applied to both new construction and existing vessel conversions utilizing gases or other low-flashpoint fuels, including methanol, regardless of size. The Guide also applies to vessels burning conventional fuels but having design features suitable to permit conversion at a future date to a particular gas or other low-flashpoint fuel-burning concept based on existing class requirements. Recognition and notations of this Guide will be offered to ships complying with the scope of the IGC Code on a case-by-case basis, provided such proposals are arranged in accordance with the requirements of the IGC Code and 5C-8 of the Marine Vessel Rules and with agreement of the Flag Administration.

The Rules for Vessels Using Gases or other Low-Flashpoint Fuels are covered under ABS Marine Vessel Rules (MVR) 5C-13-1/1.2 under the notation LFFS (Low-Flashpoint Fueled Ship). The LFFS notation may be assigned where a vessel is arranged to burn a low-flashpoint fuel other than natural gas for propulsion or auxiliary purposes and is designed, constructed, and tested in accordance with the requirements of MVR 5C-13. The equivalence of the design is to be demonstrated by the application of the alternative design criteria detailed under MVR 5C-13-2/3. For methanol applications, and subject to Flag Administration agreement, this would now be by application of MSC.1/Circ.1621.

Since both IGC and IGF Codes have been developed on a prescriptive basis for using natural gas, there are additional steps to be undertaken when burning other low flashpoint fuels. This involves a risk assessment process that is captured within both sections of the rules to enable the assignment of the applicable notation to any ship type. These additional notations recognize the application of the alternative or equivalent design approaches outlined in the IMO Codes for the burning of low flashpoint fuels other than natural gas. For example, the 'LFFS (DFD-Methanol)' notation would be assigned to an IGF Code Low Flashpoint Fueled Ship using methanol as a fuel, and the 'DFD-LPG' notation would be assigned to an IGC Code gas carrier using Liquified Petroleum Gas (LPG) as a fuel.

ABS publications that supplement the Class and statutory requirements and can facilitate the design of IGC and IGF vessels and application of natural gas or other low flashpoint fuels are tabulated in Appendix V of the ABS *Advisory on Gas and Other Low Flashpoint Fuels*. All ABS rules, guides, and guidance notes can be downloaded at www.eagle.org.

## RISK ASSESSMENT

Risk assessments and engineering analyses are required to varying extents for the use of low flashpoint fuels on marine vessels. Both the IGC and IGF Codes include such requirements, but the extent and process to be followed is to be agreed upon with the Flag Administration in each case. Where required, risks are to be analyzed using acceptable and recognized risk analysis techniques, eliminate the risks where possible, mitigate those risks that cannot be eliminated, and document the process. The risk assessment may utilize Hazard Identification (HAZID), Hazard and Operability Study (HAZOP), Failure Modes and Effects Analysis (FMEA), or other recognized risk analysis techniques, and provide valuable design recommendations. ABS can facilitate such risk assessment studies at any stage of a concept or design maturity.

For the application of other low flashpoint fuels to IGF Code ships, a risk assessment is to be undertaken to confirm that the risks from the use of the low-flashpoint fuel affecting persons on board, the environment, and the structural strength or the integrity of the ship are addressed. The IGF Code requires that consideration is given to the hazards associated with physical layout, operation, and maintenance following any reasonably foreseeable failure. The risk assessment is to consider, as a minimum, loss of function, component damage, fire, explosion, and electric shock. Similar to the process for IGC ships, the IGF Code also includes a requirement for demonstrating equivalence. Section 2.3 of the IGF Code details the process for 'alternative design' and indicates that fuels not specifically addressed by the IGF Code may be used, provided they provide an equivalent level of safety of the relevant chapters of the IGF Code. The equivalence is to be demonstrated as specified in SOLAS Regulation II-1/55, which refers to MSC.1/Circ.1212(9). Note that the adoption by IMO of MSC.1621 now provides a detailed goal- based and prescriptive requirements for the use of methanol as fuel. These interim guidelines also include a risk assessment requirement, similar to that required for the application of LNG as fuel.

The process to demonstrate an equivalent level of safety through the risk assessment process will vary depending on the complexity of the design and the extent it deviates from the prescriptive arrangements. The Flag Administration may also have requirements and expectations on the process. Therefore, dialogue with ABS and the Flag Administration at an early stage of the development process is important for the execution of a successful project and may require re-evaluation as the design matures and the complexity of the risk assessment increases.

The main activities in the risk assessment process are:

- Develop the risk assessment plan;
- Prepare and conduct the initial risk assessment; and
- Conduct an update of the initial risk assessment and/or perform additional detailed risk assessment, as applicable.

The extent of the engineering analyses needs to be acceptable to the Flag Administration.

The early adopters of methanol are spearheading the development of fuel quality criteria, fuel supply system, and equipment specifications, together with providing the experience necessary for the development of robust marine fuel standards.

For more information on risk analysis techniques, see the ABS *Guide for Risk Evaluations for the Classification of Marine-Related Facilities* and the ABS *Guidance Notes on Risk Assessment Applications for the Marine and Offshore Oil and Gas Industries.* ABS offices and specialist risk and subject matter expert groups, such as GGS, can assist at all stages of the risk assessment process. See also IACS Recommendation No.146(22) for a detailed risk assessment process tailored to meet the requirements for risk assessment as required by the IGF Code.


# DESIGN CONSIDERATIONS

## CONCEPT EVALUATION

The general safety principles of the IGC and IGF Codes provide the framework for the use of low-flashpoint marine fuels. Common safety principles such as fuel tank protective location, double barriers on fuel supply lines, ventilation and gas detection, hazardous area classification, explosion mitigation, etc. are equally applicable to all low-flashpoint fuels. However, the specific fuel characteristics may require specific safety features. For methanol, any fuel leaks produce heavier than air vapors requiring specific measures and additional detectors are necessary as the fuel is toxic. The fuel characteristics would be considered during the risk assessment analyses.

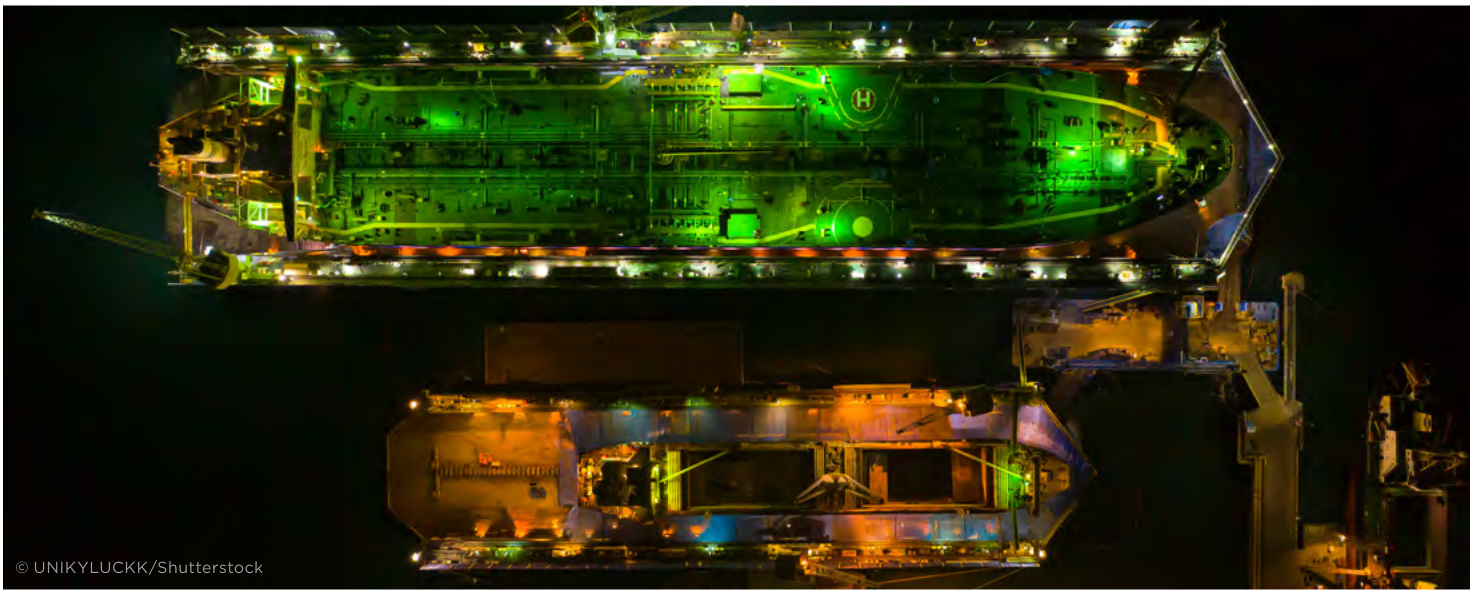
The IMO Interim Guidelines for the Safety of Ships Using Methyl/Ethyl Alcohol as Fuel cover considerations for ship design and arrangement, fuel containment system, materials, pipe design, bunkering, fuel supply, power generation, fire safety, explosion prevention, hazard area classification, ventilation, electrical installations, control systems, crew training, and operations.

Methanol does not have cryogenic complexity and is a liquid at ambient conditions. Liquid fuels such as methanol are simpler to handle and would be closer to conventional bunker vessels. In addition to methanol being traded and transported in chemical carriers for many years, there is also the experience of the Offshore Support Vessel (OSV) and Platform Supply Vessel (PSV) fleets handling methanol for the offshore industry, which can therefore also be reference points for the wider adoption of methanol as a bunker fuel. Methanol is a widely traded commodity with an existing global distribution network that could be leveraged to support marine fuel bunkering.

The trade and regulatory landscape of short-sea vessels make them ideal candidates for early adoption of new technologies such as methanol. Fuels such as methanol have strong potential to lower the carbon footprint of shipping, but one of methanol's challenges is its low energy content and the comparatively lower amount of energy it can store in the tanks of a ship. That said, compared against other alternate fuels, methanol is relatively efficient at energy storage by volume based on physical tank space. Consequently, short-sea shipping can accommodate the use of fuels with low energy content – such as methanol – that require more frequent bunkering.

The adoption of low carbon and net carbon-neutral fuels for large vessels is more challenging than for smaller ones. Using fuels with low energy content, such as methanol, would require a significant redesign, not least because their fuel tanks would need to be expanded to store enough energy for longer deep-sea travel. However, methanol is more suited to storage in near conventional fuel tanks so can be easier to accommodate in ship designs than other low-flashpoint fuels and also under MSC.1/Circ.1621 5.2.1 may be bounded by the vessel shell plating when located below the lowest possible waterline.

When used as the primary fuel, methanol can reduce $CO_2$ emissions by around 10 percent. However, methanol has the potential to be a carbon-neutral fuel in the future if it is produced renewably through biomass/biogas or renewable electricity.

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Methanol is currently thought of as a mature fuel by engine manufacturers, which have marketed engine platforms able to use them. Therefore, they can be used to meet the carbon-reduction goals of 2030 and can pave the way to carbon-neutral propulsion.

Methanol is currently more expensive than low-sulfur Marine Gas Oil (MGO), which makes it a less attractive solution under the current regulatory landscape. In addition, the shipping industry is greatly affected by fuel price volatility, therefore the supply of methanol needs to be supported by contractual measures that limit this volatility.

## BUNKERING

Fuel supply, infrastructure, and bunkering of methanol remain as challenges for its widespread adoption. Lessons can be learned and adapted from the use of LNG as marine fuel while developing bunkering infrastructure for methanol. Bunkering facilities, onboard containment systems, fuel supply systems, and marine engines are the key aspects that need to be assessed for the use of methanol as a marine fuel.

The bunkering station is to be provided with adequate ventilation and is to be preferably located on the open deck. For semi-enclosed or closed bunkering stations, effective mechanical ventilation is to be provided and may also require a risk assessment.

As a liquid fuel at ambient conditions, bunkering equipment and practices for methanol are much closer to that for conventional fuel oil bunkering. Historical expertise and best practices have been developed through the chemical tanker sector and ships subject to the IBC Code, but also through the offshore sector with the experience gained through handling methanol for drilling operations. For example, the United States Coast Guard (USCG) CG-ENG policy letter 03-12 provides USCG policy for implementation of IMO Resolution A.673(16) for the handling of hazardous and noxious liquid substances in bulk on OSVs, with specific requirements for handling methanol. The IMO has adopted Resolution A.1122(30), the Code for the Transport and Handling of Hazardous and Noxious Liquid Substances in Bulk on Offshore Support Vessels (OSV Chemical Code), which now supersedes the IMO Resolution A.673(16).

## STORAGE

In addition to achieving a lower carbon footprint, the liquid state of methanol makes it easy to store and be readily available for bunkering. The current infrastructure for methanol distribution was built for its use by the chemical industry over many decades, which ensures adequate availability, but it is thought that several more terminals will be needed if methanol is to be used in marine vessels.

Figure 5 in ABS Outlook II, shows the estimated capacity of methanol storage around the world, which would support its logistical suitability as a marine fuel for the medium-term.

For onboard storage, the low-flashpoint fuels that are liquid at ambient conditions, such as methanol or ethanol, can be stored in conventional fuel tanks and thus can be simpler to apply. Methanol is often proposed for locations below the waterline. This can promote the use of a number of ballast tanks as potential fuel tanks. However, these tanks need special coatings (zinc, etc.), and due to the low-flashpoint may require a nitrogen blanket to the tank vapor space. Regardless of the fuel or technology selected, the decision process is very vessel specific. Additional cofferdams or hold spaces are also required.

## PRIME MOVERS

MAN and Wärtsilä offer methanol-burning engines. Both engine designers have adopted the high-pressure diesel combustion process for utilizing methanol.


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The MAN engine is based on the ME-GI engine concept but instead of injecting high-pressure gas, the engine is designed to inject high-pressure liquid fuels, similar to the injection of conventional fuel oils, through a dedicated liquid fuel injector. This engine designation is 'ME-LGI' and is designed for methanol, LPG, Dimethyl Ether (DME), and other similar nominally liquid fuels at ambient or low-pressure conditions such as ammonia. For methanol, the engine has the designation 'ME-LGIM' and for LPG it has the designation 'ME-LGIP'.

The dual-fuel combustion concept, i.e., the diesel process in both oil and low-flashpoint fuel modes, is the same as for the ME-GI engine, and therefore the MCR and transient response performance is equivalent to the conventional oil-fueled engine range and operates with no fuel slip. As with the ME-GI concept, the ME-LGI engine can burn methanol (or LPG or DME or ammonia) or fuel oil over a wide-ratio depending on the operator preference, fuel availability, and relative fuel cost.

The Wärtsilä methanol-burning engine technology has been successfully demonstrated on the Stena Germanica conversion. This retrofit included converting some of the ballast tanks for methanol fuel storage, the addition of a high-pressure (600 bar) fuel pump room, installation of the double-wall fuel piping system with associated safety systems, and conversion of the 4-stroke medium-speed engines for methanol combustion.

The engine technology for the conversion is based on Wärtsilä's high-pressure natural gas injection technology, historically deployed in offshore and land-based engine applications. The high pressures in the methanol common rail system are generated by a dedicated HP fuel supply pump, located in the methanol fuel pump room, which incorporates its own methanol drain and nitrogen purge system. This off-engine fuel system was applied for the purposes of proof of concept but is one of the systems that would likely be redesigned as an on-engine HP pump and rail arrangement for production engine designs.

The engine modifications included a change of engine cylinder heads with the introduction of specially designed combined fuel oil and methanol injectors. Operation of the injector is via a dedicated hydraulic control system, with the control oil also separated from the fuel system by a sealing oil system. Combustion is initiated with a pilot injection of conventional fuel oil. Operation indicates slightly improved efficiency over the diesel variant, expected SOx and PM reductions from the clean fuel, and NOx reductions of 40-50%. The NOx reductions were not large enough to get to IMO Tier III levels, and thus would require exhaust aftertreatment, or blending water with the methanol.

Methanol distribution and available engines are still some way behind natural gas, but the real-world experience of large commercial marine ships demonstrates that methanol is a serious contender for a long-term future marine fuel.

# ONGOING RESEARCH

## INDUSTRY PROJECTS

There have been several industry projects in the past that focused on exhibiting the technological readiness of methanol engines and fuel cells. A few industry and pilot projects using methanol as a marine fuel are discussed below.

### WATERFRONT SHIPPING

The only deep-sea commercial ships burning methanol as fuel in operation currently are those with various operators from the Waterfront shipping fleet, which is the wholly-owned shipping arm of Methanex in Vancouver, Canada, the world's top methanol producer. The Waterfront shipping fleet list is tabled below for 11 ships delivered and operating as of October 2020.

| VESSEL NAME | IMO NUMBER | OWNER | BUILDER |
|---|---|---|---|
| *Creole Sun* | 9850214 | IINO LINES and Mitsui | HMD |
| *Takaroa Sun* | 9850202 | NYK | HMD |
| *Mari Kokako* | 9848687 | Marinvest | HMD |
| *Mari Couva* | 9848584 | Marinvest | HMD |
| *Lindanger* | 9725299 | Westfal-Larsen | HMD |
| *Leikanger* | 9725304 | Westfal-Larsen | HMD |
| *Cajun Sun* | 9724025 | MOL Mitsui OSK | Minami Nippon |
| *Taranaki Sun* | 9751406 | MOL Mitsui OSK | Minami Nippon |
| *Manchac Sun* | 9724013 | MOL Mitsui OSK | Minami Nippon |
| *Mari Boyle* | 9732979 | Marinvest | HMD |
| *Mari Jone* | 9725316 | Marinvest | HMD |

*Table 2: Waterfront shipping methanol-fueled tanker fleet*

### STENA GERMANICA

The Stena Germanica *Ro-Pax* ferry was converted for burning methanol in 2015. This retrofit included converting some of the ballast tanks for methanol fuel storage, the addition of a high- pressure (600 bar) pump room, installation of the double-wall fuel piping system with associated safety systems, and conversion of the 4-stroke medium-speed engines for methanol combustion.

### MS INNOGY

In August 2017, the *MS Innogy* was christened in Essen, Germany as the first methanol-powered fuel cell excursion vessel in the country. The tourist ship is supplied with green methanol that is produced nearby in the Lake Baldeney hydroelectric plant using the green electricity, water, and carbon dioxide captured from the surrounding air.

### METHANOL-POWERED RESEARCH VESSEL UTHÖRN

In August 2020, the Alfred Wegener Institute (AWI) ordered a new methanol-powered research vessel, the *Uthörn*. The 37.5m vessel will be the first methanol-fueled ship built in Germany and showcases the Fassmer shipyard's competence on new propulsion technology systems. The vessel is expected to operate in the North Sea and focus operations around the Heligoland island station operated by AWI. Fassmer expects delays where the relevant regulations are still being evaluated and the methanol drive components require new type approvals.


*Figure 4: Concept design of AWI's new research vessel Uthörn to be built by Fassmer GmbH.*

### AIDANOVA METHANOL FUEL CELL TESTS

Methanol fuel cells are to be tested onboard the cruise ship *AIDAnova* in 2021 to investigate the integration, efficiency, and operability of a fuel cell against the low-emission powering options of LNG and batteries. The fuel cells to be installed, designed, and tested by Freudenberg Sealing Technologies, have been tested in a shoreside facility and proved to have a long life of up to 35,000 operating hours. The test also investigated the development of related energy networks, energy management, and ecological and economic impacts of the methanol fuel cell system.

### NEW METHANOL IMOIIMEMAX TANKERS FOR PROMAN STENA BULK LTD.

Sweden's Stena Bulk and Swiss tanker manager Proman Shipping have formed a joint venture called Proman Stena Bulk. Proman Shipping, an arm of the world's second biggest methanol producer, Proman, was formed in 2018. It manages a fleet of 12 time-chartered vessels: nine zinc-coated and three epoxy-coated chemical tankers. In late 2019, Proman Stena Bulk Ltd. ordered two new methanol tankers from Guangzhou Shipyard International (GSI), with the first vessel to be delivered in 2022. Based on extensive tow tests between 2015-18, Stena Bulk and GSI have developed a highly energy-efficient hull form IMOIIMAX for mid-range tankers. GSI has delivered 13 of the vessels for Stena Bulk using other fuel options. The two new vessels will each have 49,900 deadweight capacity and run-on methanol dual-fuel engines. In November 2020, Proman Stena Bulk Ltd. has finalized an agreement to build an additional methanol-ready vessel.

## METHANOL AS A MARINE FUEL OPTIMIZATION RESEARCH

Some research projects are proceeding on land before testing onboard. These types of research projects are focusing on engines fueled by either pure methanol or a methanol mix. Some of these research projects are described below.

### HYMETHSHIP

A European consortium of 13 members have been working since 2018 to develop an established methanol ship sourced from renewable energy. Using sustainable methanol produced onshore, the HyMethShip uses an onboard carbon capture system to produce hydrogen and $CO_2$. The hydrogen is then sent to a specialized reciprocating combustion engine for power generation, and the $CO_2$ is stored onboard and returned to the shoreside methanol production process. Therefore, this closed-loop process powered by renewable energy will be entirely carbon-neutral and emissions-free. Before installation on a ship, the technology will be tested at full scale onshore. The consortium is working to ensure that the system can be implemented safely using risk assessments while assisting with the development of regulations for this type of novel system.

### GREEN MARITIME METHANOL CONSORTIUM

A large group of industry partners called the Green Maritime Methanol Consortium has joined to study possible solutions for renewable methanol as a marine fuel. As of early 2020, the partner Pon Power has initiated an engine test program that uses a modified Caterpillar 3508 gas engine to run on 100% methanol. Controlled testing of an engine on pure methanol allows researchers to investigate engine optimization of the engine mechanics and emissions safely and strategically.

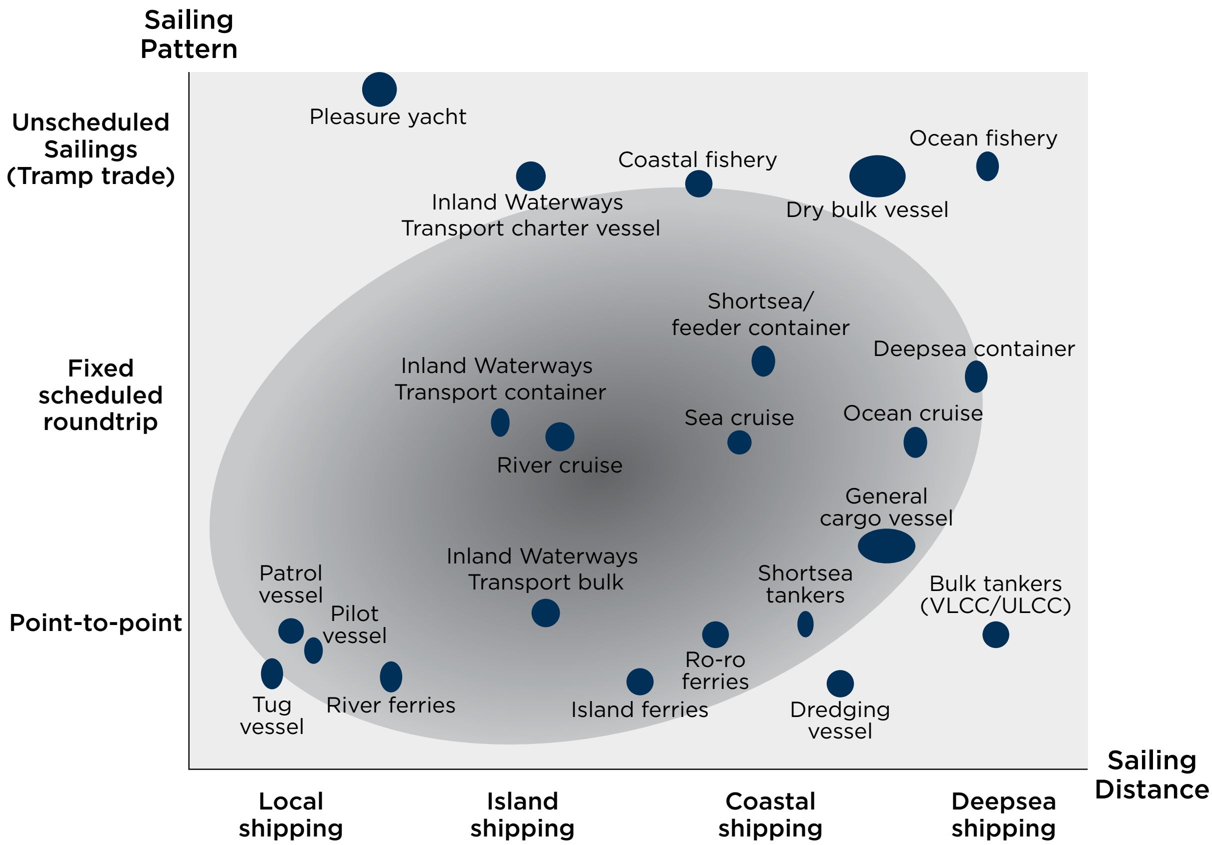




*Figure 5: Heatmap of methanol-applicability of shipping segments*

Another consortium partner, the Netherlands Defence Academy (NLDA), is testing an engine for dual fuel methanol performance. The MAN 4L20/27 engine tests will include two mixtures, one that is stabilized by an emulsifier, and another blended mechanically, to evaluate engine performance with various fuel compositions and injection mechanisms.

#### DANISH TECHNOLOGICAL INSTITUTE STUDYING METHANOL ADDITIVES FOR DIRECT USE IN MARINE ENGINES

The Danish Energy Agency is supporting research efforts by the Danish Technological Institute to study optimizing additives for methanol to allow it to be burned in traditional diesel engines. Only minor modifications to the engines are expected to transition between conventional marine fuels and methanol, including air preheating and an additional fuel booster. The resulting service package could be installed during a ship retrofit and will allow the modified vessels to run without pilot fuel and enable carbon-neutral or zero-emissions applications, especially with the use of renewable methanol.

## METHANOL BUNKERING INFRASTRUCTURE PROJECTS

Other ongoing research and industrial projects are focusing on scaling up methanol to become available for use in the wider transportation industries. For use in marine applications, infrastructures such as methanol bunkering facilities and fuel supply systems are to be developed.

#### RENEWABLE FUEL PRODUCTION FACILITY PLANNED IN DENMARK

A partnership between Copenhagen Airports, A.P. Moller-Maersk, DSV Panalpina, DFDS, SAS, and Ørsted has formed to scale up the production of industrial hydrogen in Denmark, with a vision of producing sustainable fuel for the road, air, and marine transportation networks by 2030. The production facility will be powered by renewable offshore wind energy, local recovered and captured carbon, and use electrolyzers in several stages. The offshore wind could be sourced from the Rønne Banke turbines expected to be installed off the island of Bornholm. By 2027, the project expects to increase electrolyzer output to 250 MW, and use sustainably captured $CO_2$, to supply sustainable methanol to Maersk vessels. A further stage expects to scale up again, using a 1.3 GW electrolyzer to supply over 250,000 tonnes of fuel to the local industry, including busses and airplanes.

Denmark aims to reduce carbon emissions in 2030 by 70%, compared to 1990, by implementing immediate change to their energy infrastructure and encourage sustainable fuels to replace traditional fossil fuel-based emission sources.


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#### CHINESE STUDY METHANOL TECHNICAL AND OPERATIONAL REQUIREMENTS FOR USE AS A MARINE FUEL

The China Waterborne Transportation Research Institute and the Methanol Institute are supported by Methanex and Shanghai Huayi Energy Chemical to examine the feasibility of methanol as a marine fuel in China. Historically, China has been one of the largest producers of methanol in the world, mainly in association with coal and other fossil fuel production. It is also one of the largest consumers of methanol, as the chemical is used widely in manufacturing. Therefore, the study will be based on China's current methanol availability and infrastructure concurrently with China's shipping industry. The results are expected to be a guidance and policy roadmap to adopting methanol as a marine fuel in China.

## PROJECTED ROLE OF METHANOL AS A MARINE FUEL

The benefits of reduced emissions from burning methanol could be a significant contributor to reducing greenhouse gas emissions from the maritime industry. Existing methanol trade infrastructure can also be an important factor for the cost and availability of methanol over other alternative fueling options.

One of the main challenges to owners during this fuel transition is to decide on an alternative fuel to prepare for 2050. Early adoption of such fuels depends on the demand and the supply landscape. In the case of methanol, even though its trade is evolved, its many uses and demand for manufacturing may not allow surplus for maritime use without incentives. Due to this widespread use of methanol across the globe, the marine industry can at most claim a fraction of the amount available unless methanol is produced synthetically. However, this option can also incur extra costs.

The Methanex Corporation, one of the largest producers and suppliers of methanol, is a source of information for methanol prices, supply infrastructure and safe handling practices. The Methanol Institute is also a significant player in this sector promoting the use of methanol as a fuel. Additional information on methanol as a marine fuel is available through the FC Business Intelligence Ltd. 'Methanol as a Marine Fuel Report' and the Methanol Institute 'Methanol Safe Handling Manual'.

The use of methanol as a fuel in methanol carriers for propulsion and power generation, along with the development of efficient and feasible dedicated propulsion systems, has already seen an increase in new build cargo vessels powered by methanol. If methanol is produced renewably, these tankers could have an even greater potential to reduce life-cycle emissions while concurrently improving the renewable methanol fuel supply chain for other applications.

The use of methanol as a fuel in dual-fuel marine engines may allow for robust operations with various types of alternative fuels in the future. Such applications may use methanol when it is available, with the option to burn other fuels at the convenience of availability and economy.

The advantage of methanol over LNG or other gas fuels is its liquid state and ability to re-purpose existing infrastructure to include engines and vessels with efficient retrofits. Methanol is significantly easier and more economical to store on board than gas. Retrofitting a vessel's tanks from conventional fuel oil, ballast, or slop to hold liquid methanol fuel is also easier than installing LNG tanks.

One of the challenges of methanol as an alternative fuel is the lower energy content when compared to conventional fuel oils. However, as methanol is a liquid at ambient temperature and pressure, tanks can be converted with a minor retrofitting to hold larger volumes of methanol required for an equivalent amount of energy. Further methanol applications in marine fuel may only require a scale-up of existing trade, storage, and generation activities. Bunkering facilities and fuel supply systems are to be developed and scaled.

Ongoing research is striving to rapidly scale up methanol availability in terms of infrastructure as well as onboard applications and installations. Figure 7 shows the projected marine fuel use to 2050 as the industry strives to meet the GHG emissions-reduction targets mandated by the IMO.

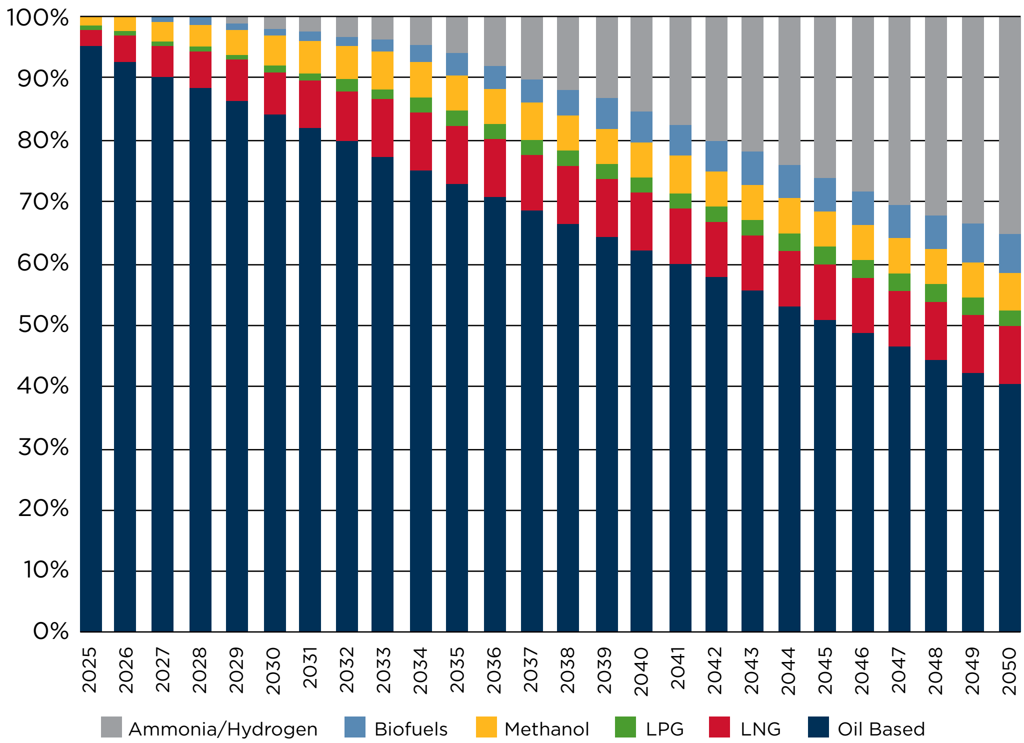


*Figure 6: Projected marine fuel use to 2050*

## ABS SUPPORT

It is to be noted that the information provided in this document is generic. For specific guidance on methanol as a marine fuel, please contact your local ABS office.

ABS can assist owners, operators, shipbuilders, and original equipment manufacturers as they consider the practical implications of the use of methanol as fuel. Services offered include:

- Risk assessment
- Regulatory and statutory compliance
- New technology qualifications
- Life cycle and cost analysis of methanol fueled-vessels
- Vessel/fleet benchmarking and identification of improvement options
- EEDI verification and identification of improvement options
- Optimum voyage planning
- Alternative fuel adoption strategy
- Techno-economic studies
- Cybersafety notations and assessments
- Contingency arrangement planning and investigations


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## APPENDIX II - LIST OF ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| **ABS** | American Bureau of Shipping |
| **AWI** | Alfred Wegener Institute |
| **CCTV** | Closed-Circuit Television |
| **CO** | Carbon Monoxide |
| **$CO_2$** | Carbon Dioxide |
| **$CH_3OH$** | Methanol |
| **DF** | Dual Fuel |
| **DME** | Dimethyl Ether |
| **FMEA** | Failure Modes and Effects Analysis |
| **GHG** | Greenhouse Gas |
| **GSI** | Guangzhou Shipyard International |
| **HAZID** | Hazard Identification |
| **HAZOP** | Hazard and Operability Study |
| **HFO** | Heavy Fuel Oil |
| **IACS** | International Association of Classification Societies |
| **IBC Code** | International Bulk Chemical Code |
| **IDLH** | Immediately Dangerous to Life or Health |
| **IGC Code** | International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk |
| **IGF Code** | International Code of Safety for Ships Using Gases or other Low-Flashpoint Fuels |
| **IMO** | International Maritime Organization |
| **IR** | Infrared |
| **ISO** | International Organization for Standardization |
| **LCA** | Life Cycle Analysis |
| **LFFS** | Low Flashpoint Fueled Ship |
| **LNG** | Liquified Natural Gas |
| **LPG** | Liquified Petroleum Gas |
| **MAN** | MAN Energy Solutions |
| **MARPOL** | The International Convention for the Prevention of Pollution from Ships |
| **ME-LGIM** | MAN engine identifier – Liquid Gas Injection Methanol |
| **MEPC** | Marine Environment Protection Committee (IMO) |
| **MGO** | Marine Gas Oil |
| **MSC** | Maritime Safety Committee (IMO) |
| **MVR** | Marine Vessel Rules |
| **$NH_3$** | Ammonia |
| **NIOSH** | National Institute for Occupational Safety and Health |
| **NOx** | Nitrogen Oxides |
| **OSHA** | Occupational Safety and Health Administration |
| **OSV** | Offshore Support Vessel |
| **Outlook I** | ABS publication *Setting the Course to Low Carbon Shipping: 2030 Outlook/2050 Vision* |
| **Outlook II** | ABS publication *Setting the Course to Low Carbon Shipping: Pathways to Sustainable Future* |
| **PM** | Particulate Matter |
| **ppm** | parts per million |
| **PSV** | Platform Supply Vessel |
| **SDS** | Safety Data Sheets |
| **SOLAS** | International Convention for the Safety of Life at Sea, 1974, as amended |
| **SOx** | Sulfur Oxides |
| **Syngas** | Synthesis Gas |
| **TWA** | Time-Weighted Average |
| **USCG** | United States Coast Guard |

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