NANYANG TECHNOLOGICAL UNIVERSITY SINGAPORE

Green Marine Methanol Challenges: Fuel Quality, Testing Standards, and Quality Assurance

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Bunkering with Off-Spec Fuel Remains a Significant Issue

The Maritime Executive
INTELLECTUAL CAPITAL FOR LEADERS

Warnings of Recent Spike in Off-Spec Marine Fuels Including VLSFO in Europe

More than 45% of the global VLSFO supply does not meet ISO standards.

- January 2025

Poor Blending & Barge Contamination – Catalytic Fines

Hard Sludges from Filters, Pipelines, Purifiers

Excessive Filter Clogging

Fuel Plunger Stuck in the Top Cover

Photo credit: VPS Seminar (Sept 2025)

Inconsistent Fuel Quality Can Lead to Operational Disruptions and Downtime!

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Fuel Purity Concerns

The Houston Fuel Quality Problem 2023

- Fuel supplied in the US Gulf region, 30 cases stemmed from supplies in the Houston area, and spread to 15 cases in Panama and 5 in Singapore.
- Common problem: sticking and seizure of fuel-injection system components and blocking of fuel filters.
- Damage to the engine, the cost of repair, ships suffered loss of power and subsequent loss of propulsion whilst at sea → ***BAD BUNKERS***

Source: Baltic Exchange (2023)

Sludge Formation in Filters and Fuel Pump Plunger

Image credit: VPS (July 2023)

- GC-MS: Dicyclopentadiene (DCPD) and associated isomers
- DCPD ↑ fuel viscosity → damage to the fuel injection system.

How can the shipowners better protect themselves?

Monitoring and Testing: *Certificate of Quality, Testing Standards, Fuel Specifications*

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Evolution of Fuel Specifications

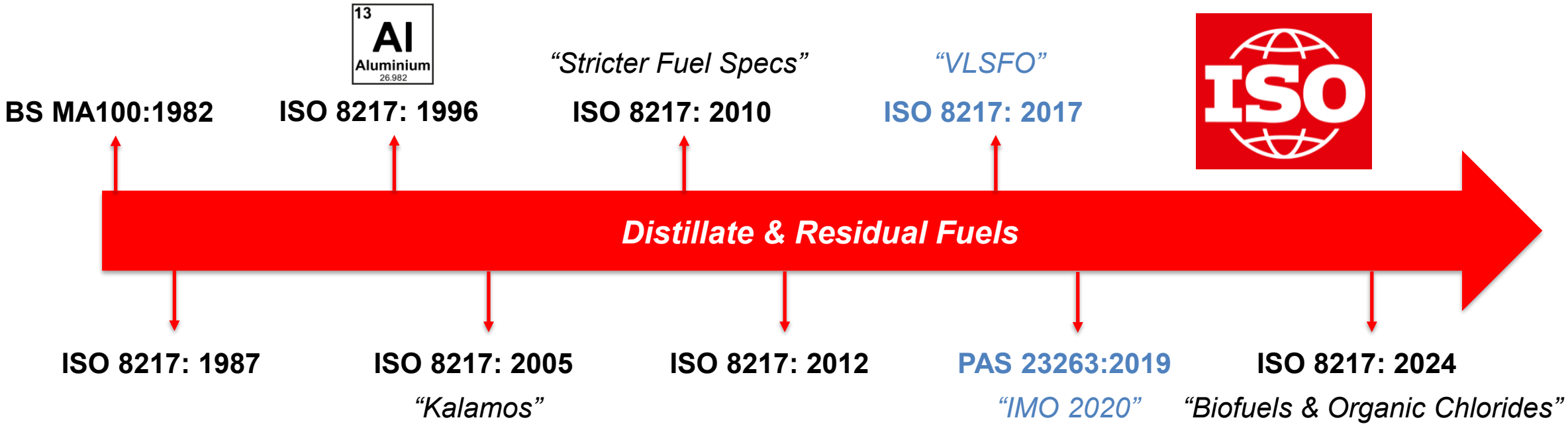
20 December 2019

IMO 2020 - cleaner shipping for cleaner air

From 1 January 2020, the global upper limit on the sulphur content of ships' fuel oil will be reduced to 0.50% (from 3.50%). The reduced limit is mandatory for all ships operating outside certain designated Emission Control Areas, where the limit is already 0.10%.*

IMO INTERNATIONAL MARITIME ORGANIZATION

Widespread Use of Very Low Sulphur Fuel Oil (VLSFO)



Fuel Compositions, Technological Advancements, Environmental Imperatives

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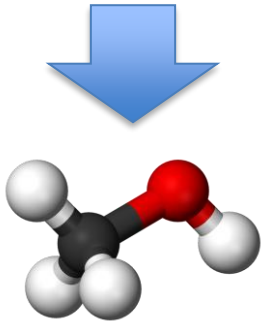
Fuel Compositions

- Key Quality Parameters:
  - Sulphur content,
  - Viscosity,
  - Density,
  - Water content,
  - Contaminants: Catfines (Al, Si), COC, Inorganic acids

Efficient Ship Operations & Longevity of Machinery



Methanol

Alternative Fuels?

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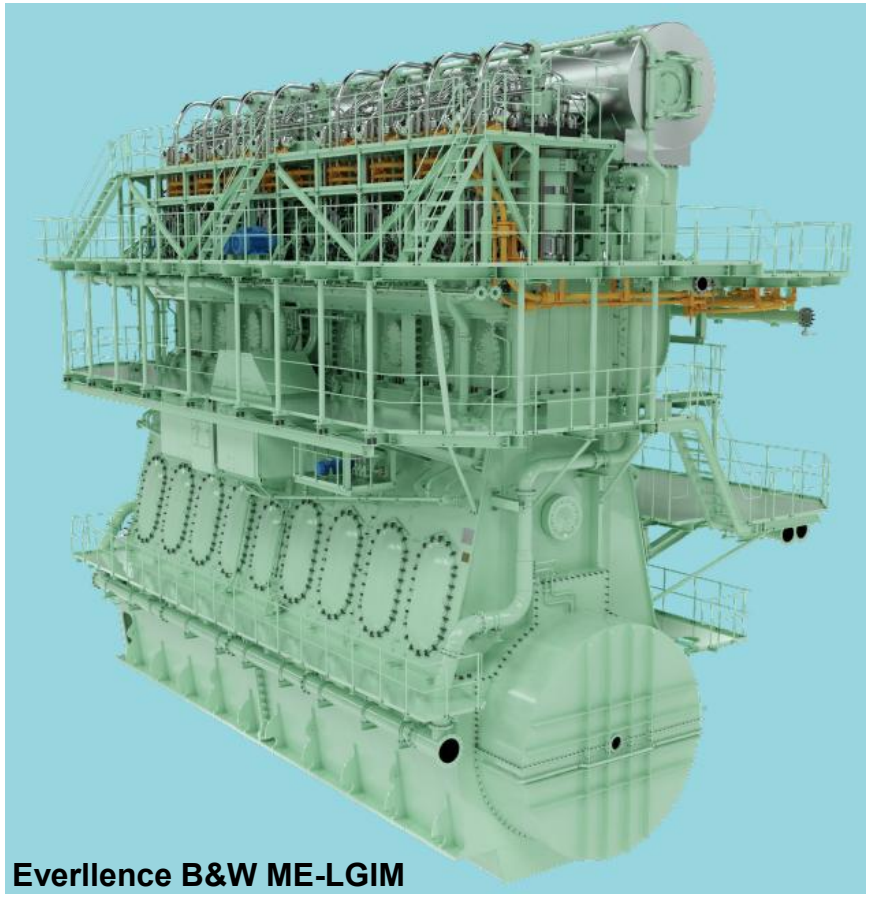
Technological Advancements

Alternative Fuels

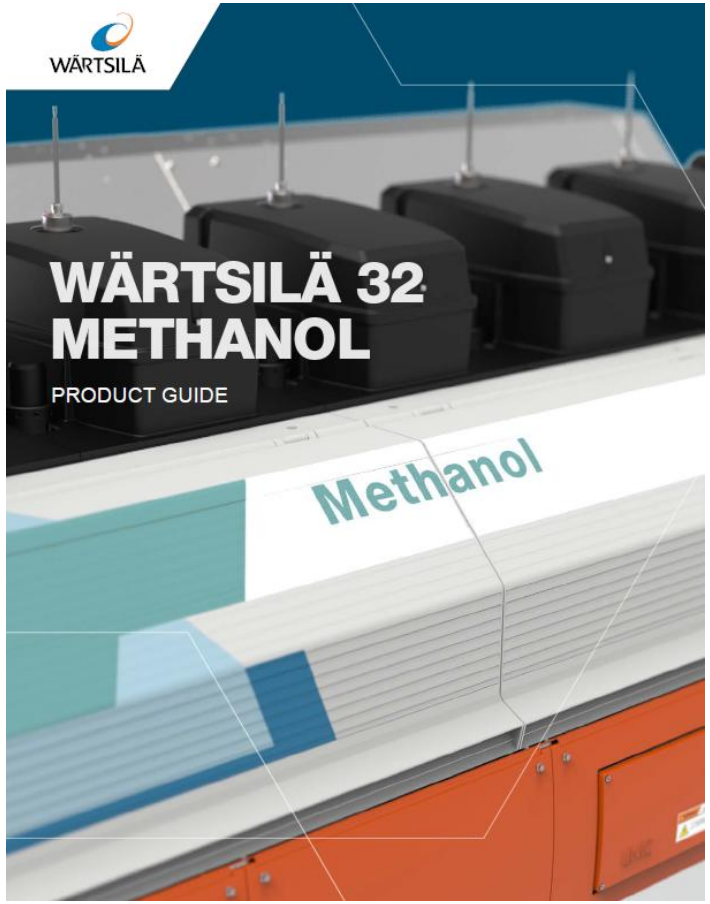
Niels DeVries Master Thesis, TUDelft (2019)

Stena Line (2020)

Methanol Engines



Everllence (2025)



Wärtsilä (2023)

How does fuel quality affect engine performance?

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Environmental Implications

International Shipping

- Shipping contributes ~3% of global CO_2 emissions
- 26% of all human-induced CO_2 is absorbed by the ocean
- Decarbonization Goals: 40% CO_2 emission reduction by 2030 compared to 2008, net-zero GHG emissions by 2050

Marine Digital (2024)

Environ. Sci. Technol. **2024**, 58, 18508

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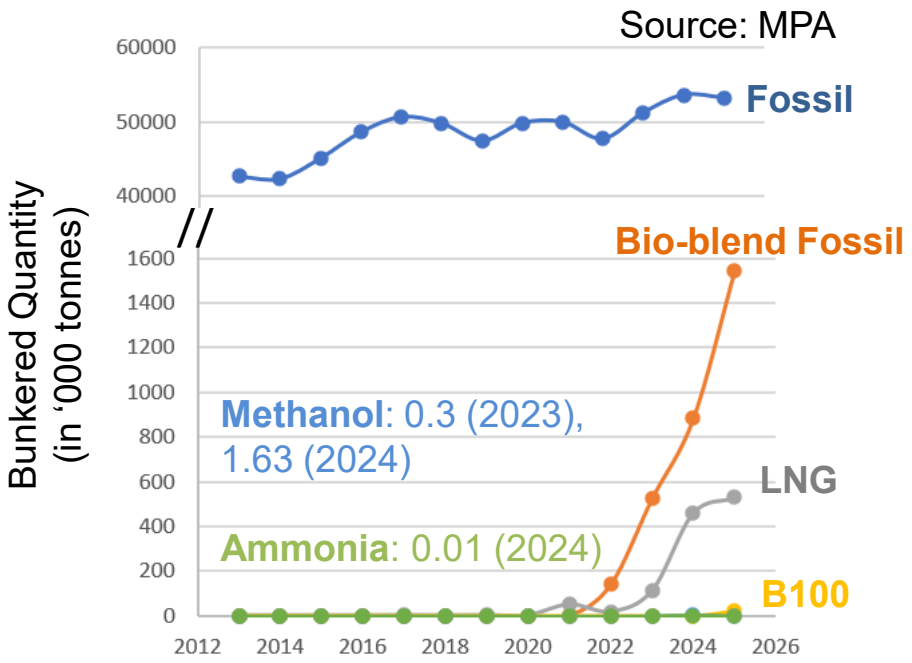
New Fuel Challenges: Daunting Tasks Ahead

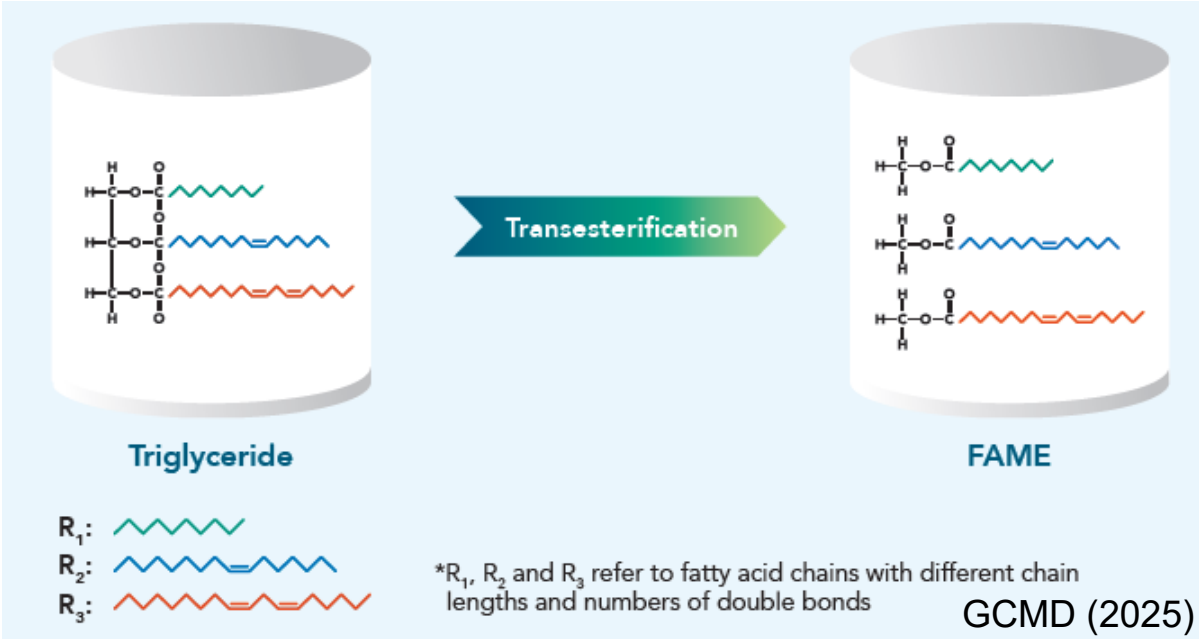
Emergence of Cleaner Fuels

Singapore Bunker Sales (2013 - 2025)

Source: MPA



Biofuels: FAME fingerprinting



- TR140 Specification for Marine Biofuels, Biofuels Fingerprinting
- TR129 Methanol Bunkering

How to improve consumer confidence for Green Methanol?

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Outline

Methanol

Testing Standards → Fuel Quality → Quality Assurance → **Green Shipping**

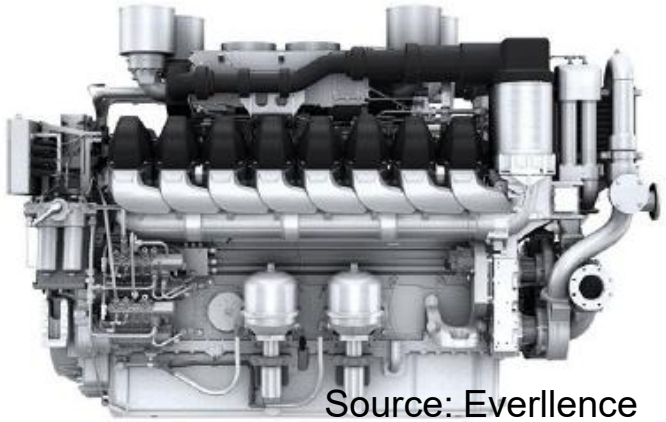
Environmental Protection & Regulatory Frameworks


Source: SGS

Existing Framework & Testing Standards

- IMO Net Zero Framework
- ISO Standards
- China Standards

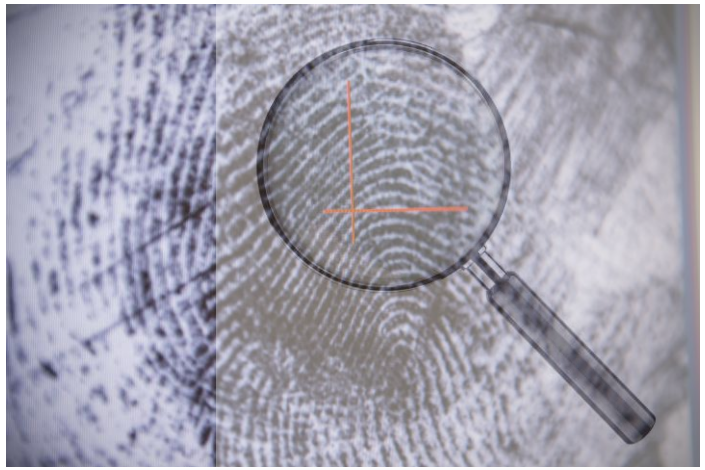
Technological Advancements


Source: Everllence

Fuel Quality

- Key Parameters
- Engine Health
- Operational Efficiency

Market Development & Industry Confidence



Quality Assurance

- Fuel Authentication
- Fingerprinting Methods

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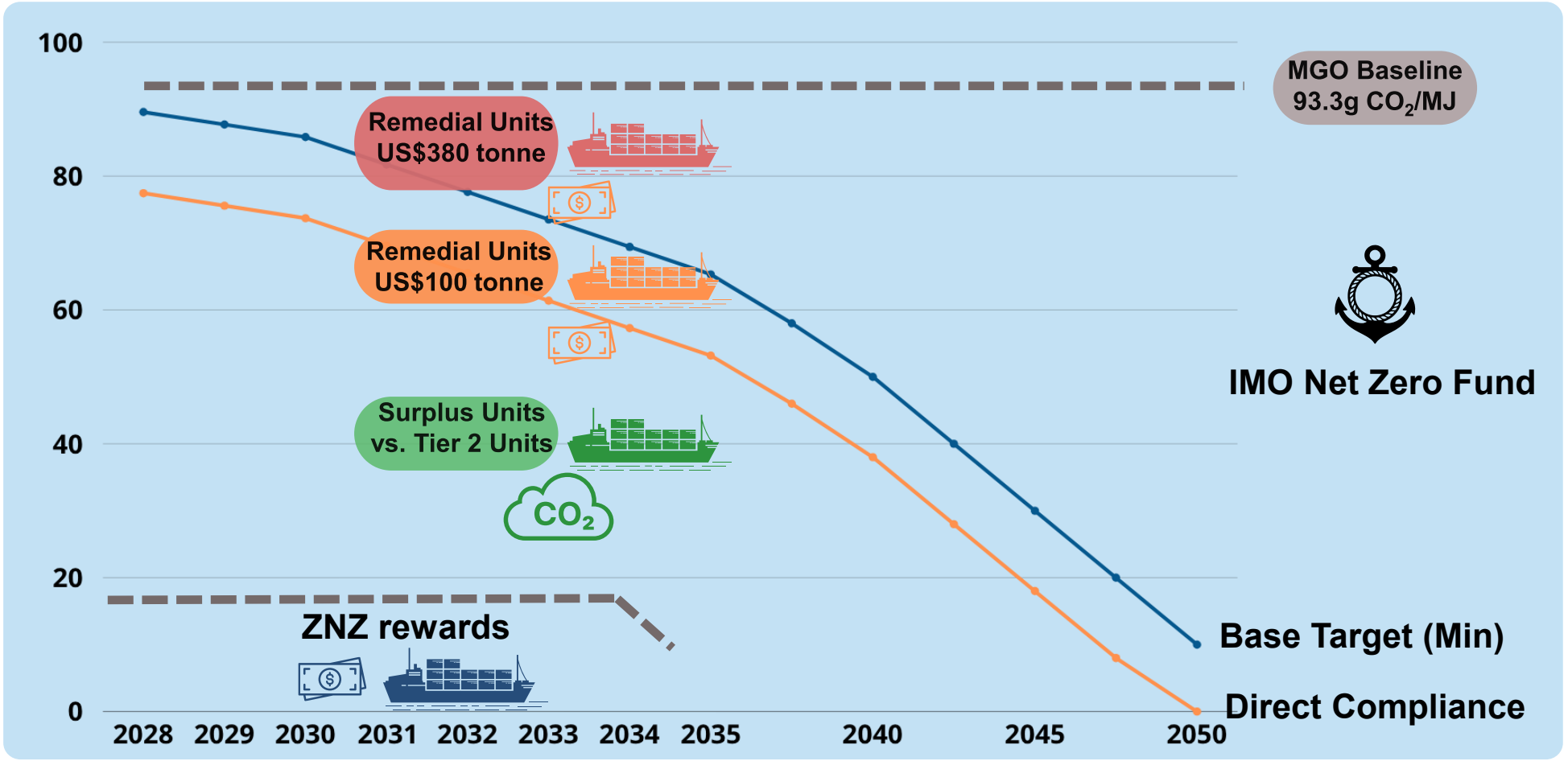
Decarbonization in Maritime Sector

IMO Net Zero Framework



- Z-factors (IMO)
- Tier 1 Direct Compliance Target (2028): 73.71 g CO_2 eq/MJ
- Tier 2 Base Target (2028): 85.84 g CO_2 eq/MJ
- LCA GHG emissions: (in g CO_2eq/MJ)
  - *HVO ~15
  - *FAME ~ 20.8
  - ^BioMethanol ~ 16
  - &BioMethanol ~ 30

Marquis Energy Global (2025)

Green Methanol is a Solution!

Source: *IMO ,^Sustainable Ships,& MESD

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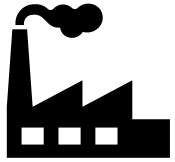
Methanol Fuel Standards (2023/2024)

IMPCA (2024) & ASTM D1152 (2024)

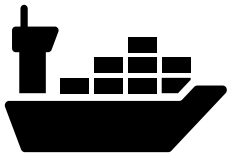



- Cater to a broad range of methanol users
  - Electronics and **pharmaceutical** industries
  - **Raw material** to produce formaldehyde & other chemicals
- Only one methanol grade specified
- Specifications need to adhere to the **most stringent** quality attributes required by methanol users
- Water content, sulfur content, chloride content

GB/T 42416

- M100 methanol fuel specifications for **motor vehicles**: Internal combustion engines (ICE)
- GB/T 42416 imposes organic and inorganic **chloride** content
- Alkalinity, sodium content, and iron content

ISO 6583 & T/CIQ 70-2023



- **Marine** methanol fuel specifications: Internal combustion engines (ICE)
- ISO 6583 imposes restrictions on methanol content: MMA, MMB & MMC
- **Water content**
- **Lubricity** tests are specified
- T/CIQA 70-2023 imposes restrictions on methanol content and water content

Further investigation on the relevance of water, chloride, sodium, and iron content

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Fuel Quality: Key Parameters

Water Content in Methanol-Fuelled Engine

Ignition & Combustion

Fuel Mixture (v/v)	Research Octane Number (RON)	Cetane Number (CN)
100% methanol	109.6	3
95% methanol / 5% water	110	NA
90% methanol / 10% water	114	2
Gasoline	90-100	NA
Diesel MGO	15-25	38-53

- ↑ water content, RON ↑ but CN ↓
- CI engine: ↑ water content, **ignition problem** (low CN) → solved by ignition improver, lubricants, pilot fuel

Corrosion

Fuel Mixture (v/v)	Viscosity (Cp)	Surface Tension (nN/m^2)
100% methanol	0.557	22.51
99% methanol / 5% water	0.580	NA
95% methanol / 10% water	0.672	NA
90% methanol / 10% water	0.788	23.93

Data extracted from (Carr & Riddick, 1951), (Lide, 2004)

- ↑ water content, surface tension of the methanol-water mixture ↑
- Pure methanol has very **poor lubricity**

Lubricants and test standards for lubricity are needed for marine applications!

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Sulfur and Chloride Content in Methanol Fuel – Materials Compatibility

SCC of Carbon Steel

Stepchangeinsafety.net (Mar 2019)

Cracks of 300 series SS

Visible Cuts on Combustion Chamber

Worn-Out Seal

Source: Everllence B&W ME-LGIM Service Report 2021

- Methanol Stress Corrosion Cracking (MSCC)
- Stress Chloride Cracking (SCC)
- Sulfide Stress Cracking (SSC)

- High methanol content can cause shrinkage, swelling, hardening, or softening of elastomers in the fuel system.

Corrosion rates and mechanisms variation in the presence of sulfide and chloride!

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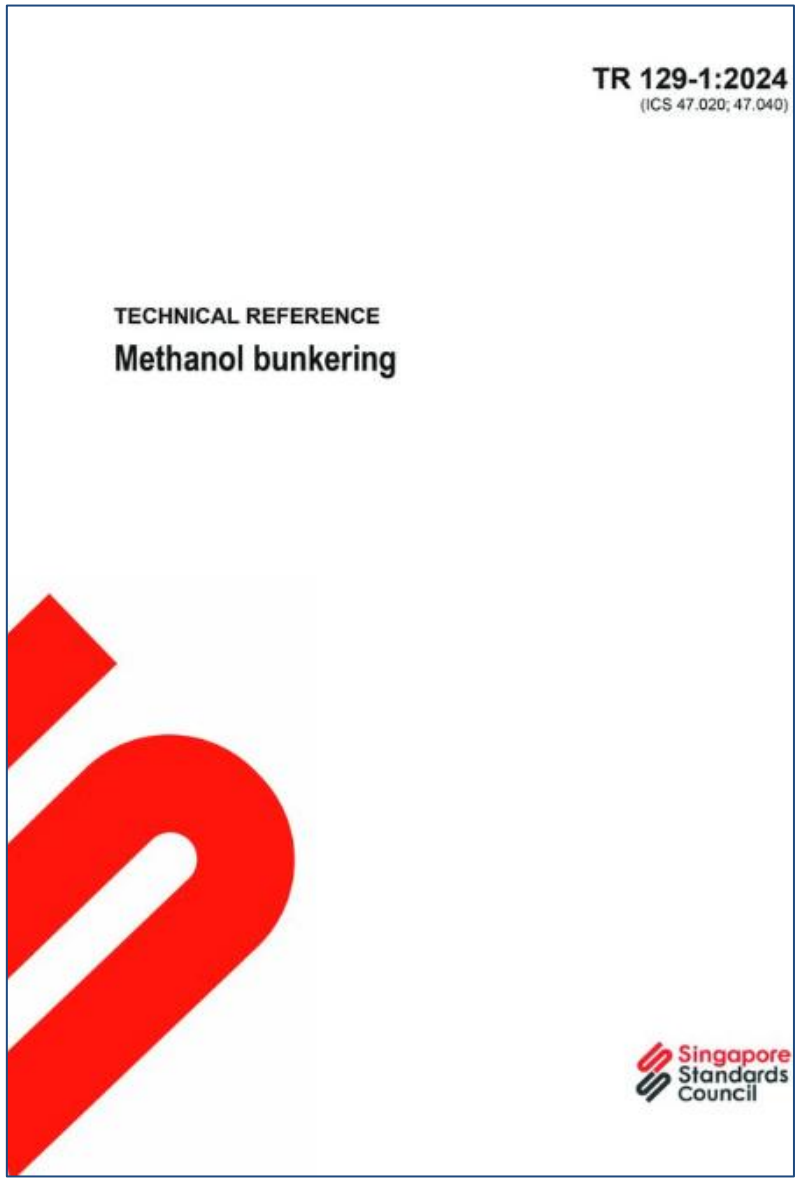
Quality Assurance

Technical Quality of Methanol

- **International Bunker Industry Association (IBIA)**
  - Industry Best Practices - promote standards to improve overall quality in the global fuel sector.
  - Methanol Bunkering Workshop, Masterclass, Training Programme.

- **Testing Labs**
  - Lubricity test: High Frequency Reciprocating Rig (HFRR) Test

- **Regulatory Oversight:**
  - Government bodies, like energy regulatory authorities, oversee and enforce fuel quality standards and safe handling - TR129



Source: Singapore Standards Council (2024)

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Sustainable Quality of Methanol

- Methods: **Physical Tracer Dosing**, **Certification System**, **Fingerprinting**
- (1) Dosing with Physical tracer – a way to identify the fuel from the point of dosage
- (2) Certification: Under the EU (RED III) and FuelEU Maritime, sustainability must be demonstrated through traceable feedstock certification systems; ISCC Certification System

~1.8 Million Tons of Fraudulent ISCC-Certified Palm Oil Mill Effluent (POME) Entered the EU in 2023

ISCC
International Sustainability & Carbon Certification

Palm oil in disguise?

How recent import trends of palm residues raise concerns over a key feedstock for biofuels

April 9, 2025

T&E

ISCC Response to Recent Suspected Cases of Mislabelling of Advanced Biodiesel

Source: The Transport & Environment (2025)

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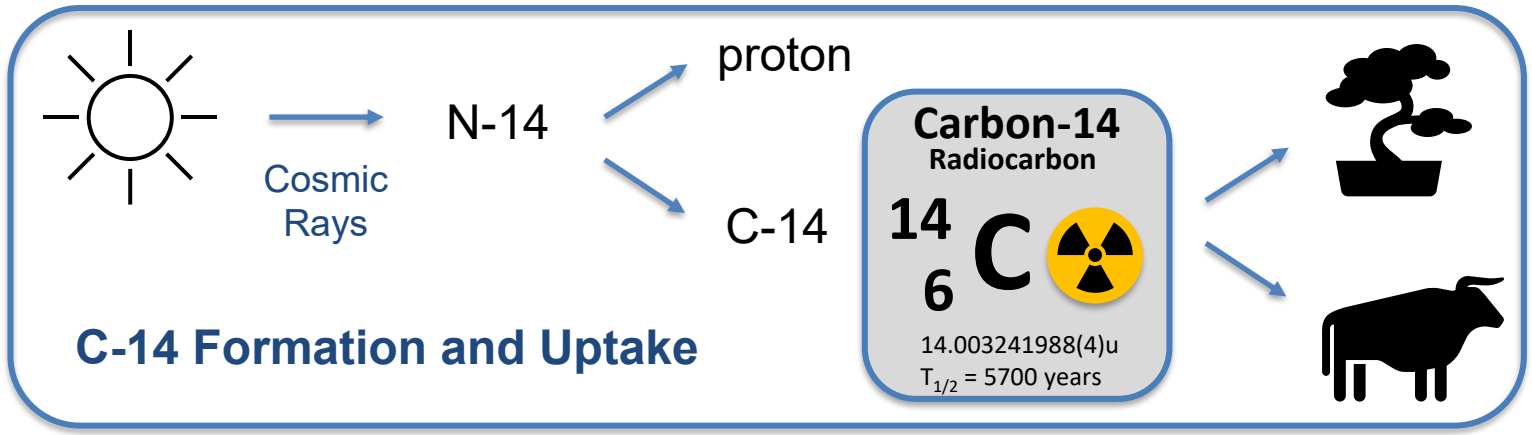
Environmental Classification of Methanol

- (3) Fingerprinting - a way of profiling the origin of a fuel based on its measurable properties.
- Methanol production: catalytic hydrogenation of carbon monoxide (CO) or carbon dioxide (CO_2)
- Measurable properties: radiocarbon C-14 levels to identify the carbon source of the fuel pathway.

Types of Methanol	Production Process
Green Methanol: ○ Bio-Methanol ○ E-Methanol	 Produced using biomass as feedstock Produced from CO_2 using electricity from renewable sources
Blue Methanol	Produced from hydrogen using CO_2 from renewable and non-renewable sources
Grey Methanol	Produced from natural gas
Brown Methanol	Produced from coal



C-14 Formation and Uptake

Any material > 50000 years does not contain C-14!

Fossil C vs. Biogenic C

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Outlook: Green Methanol Marine Fuel

Methanol

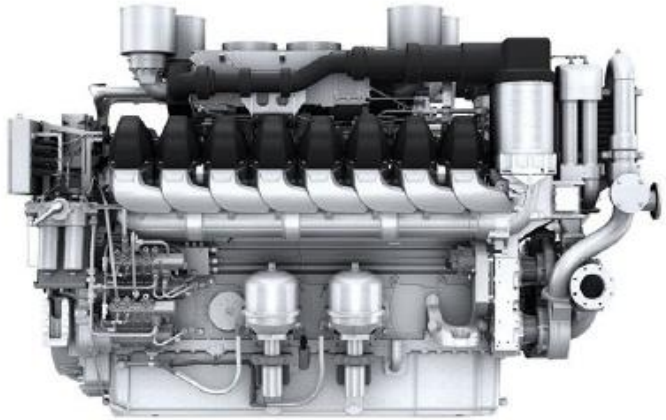
Testing Standards → Fuel Quality → Quality Assurance → **Green Shipping**

Environmental Protection

Source: SGS

- **Testing and Analysis:**
  - Laboratory Analysis
  - Field Testing Kits
- **Standards Development**
- **Industry Best Practices**

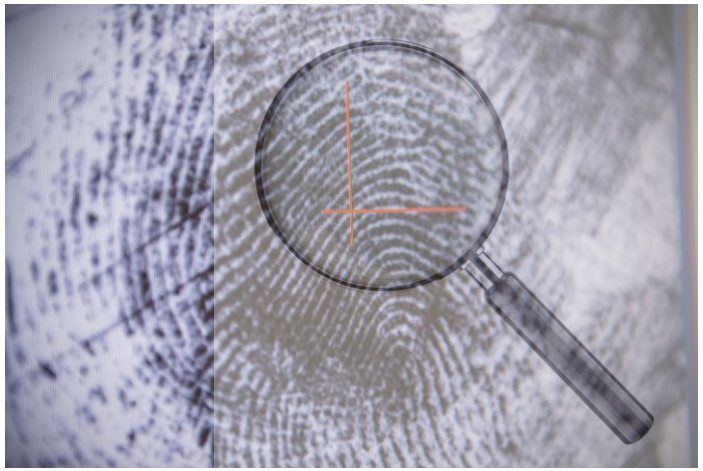
Technological Advancements



Source: Everllence

- **Leading OEMs:**
  - Materials Compatibility
  - Fuel System Design
- **Regulatory Oversight**
  - Operational Guidelines

Market Development



- **Quality Management Systems:**
  - Certification, Fingerprinting
- **Supply Chain Monitoring:**
  - Production, Bunker Stations

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Thank You

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