E-Meeting: Closing the Gaps in Bio/E-Fuels - Standards, Regulation, and Market Readiness

Alternative Fuels in the Shipping Industry
Requirements, Standards and Regulations

November 4th, 2025

Tec4Fuels – Werner Willems

Competence Center for Fuels and Energy

Association for Fuels and Energy

Advocacy for the Petroleum Industry in Germany

- Fuels and Energy
- Technology
- Innovation
- Dialogue
- Member of „Fuels Europe“

https://www.en2x.de

Products & Application-oriented Services

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- Testing
- Engineering
- Technical Consulting
- Fuel-Check

https://www.tec4fuels.com

Research and Development

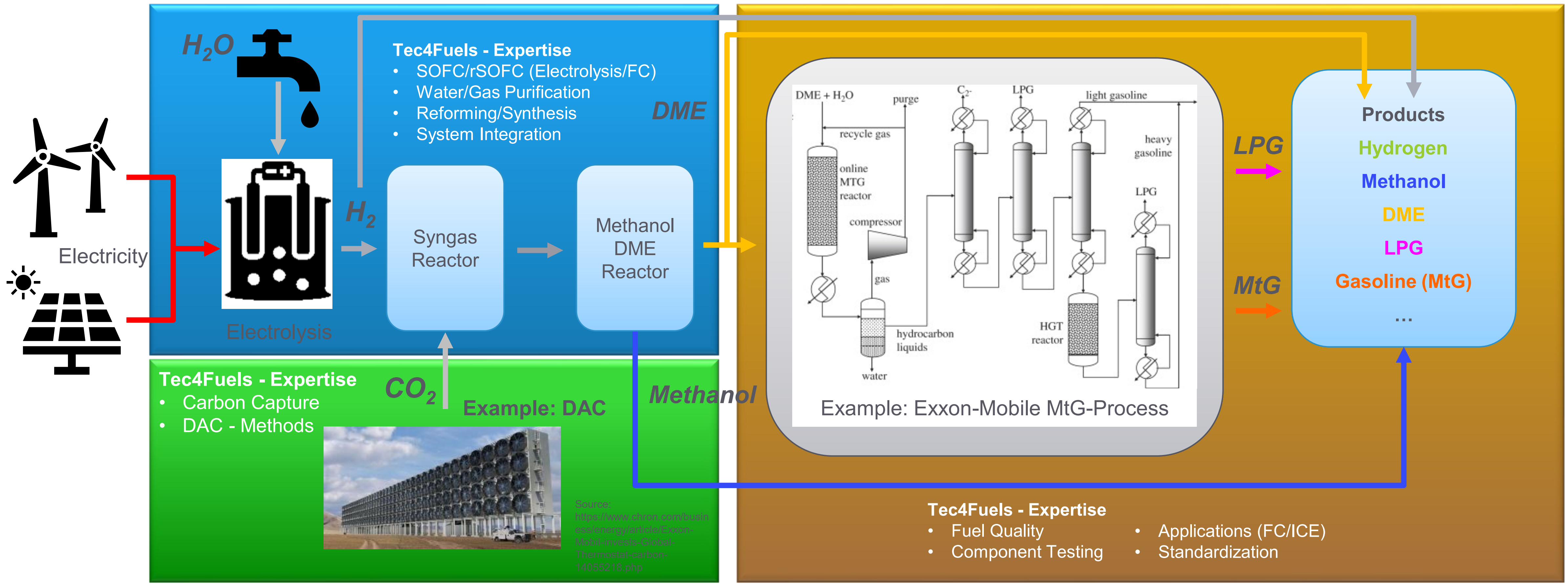
Publicly funded Research Projects

- Fuels and Lubricants
- Efficiency Technologies
- High-temperature Technologies

https://www.owi-aachen.de

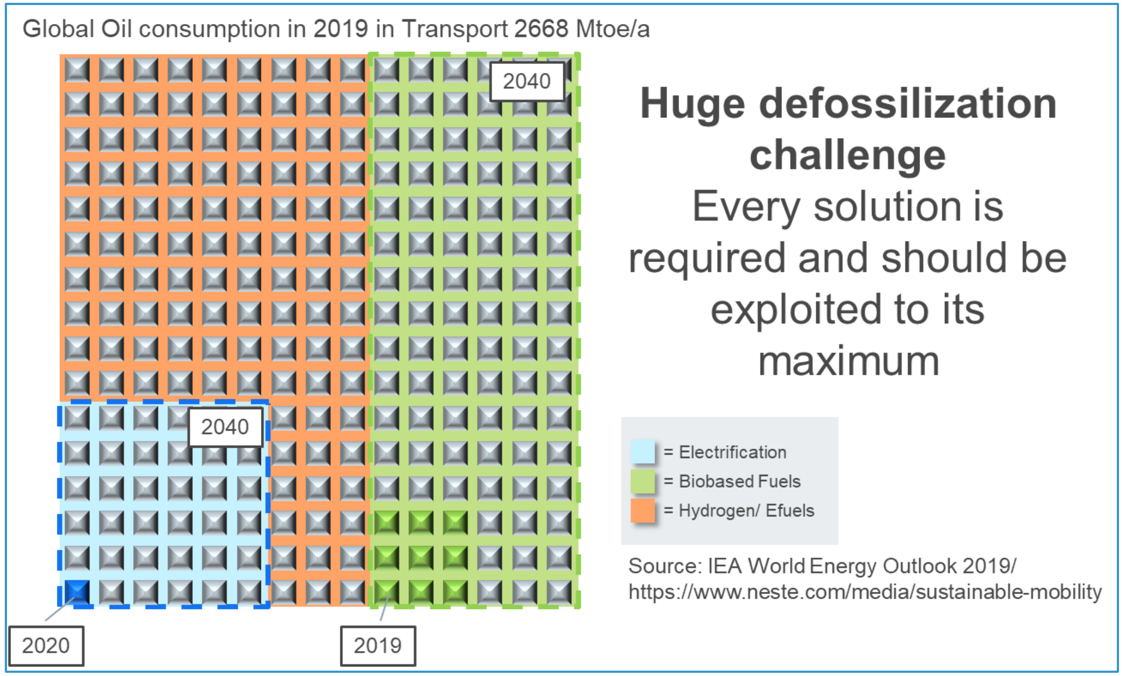
TEC4Fuels - Sustainable energy carriers for green transportation, power, and products

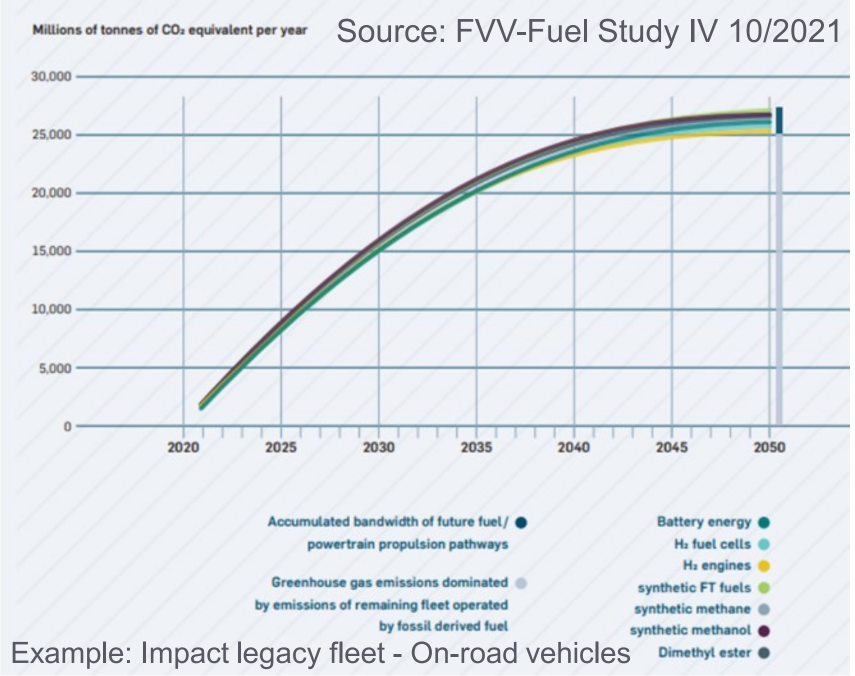
Example: Integrated Methanol-based-P2X-Concept providing multiple products for local and remote applications



Comprehensive Concept to provide products for Heating, Cooking, Fuels for Transport,
Renewable Energy-Carrier for remote-applications (i.e. energy/H_2-imports for Europe)

Defossilization Challenge for 2030 and beyond

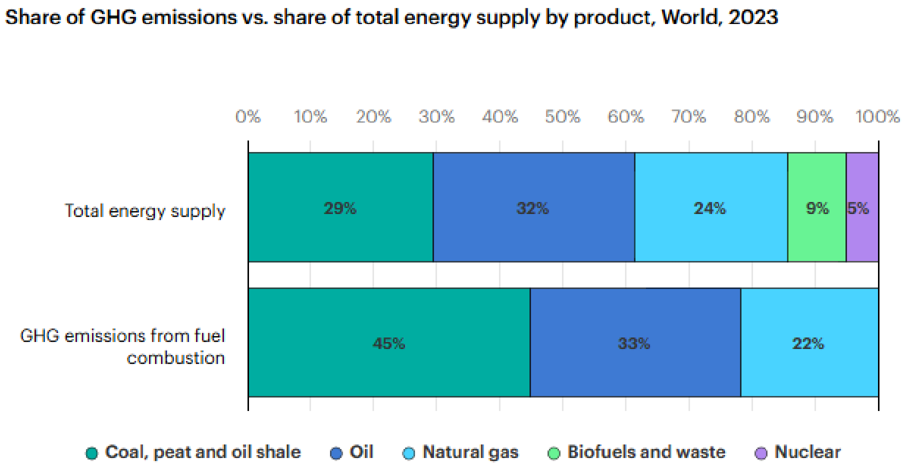




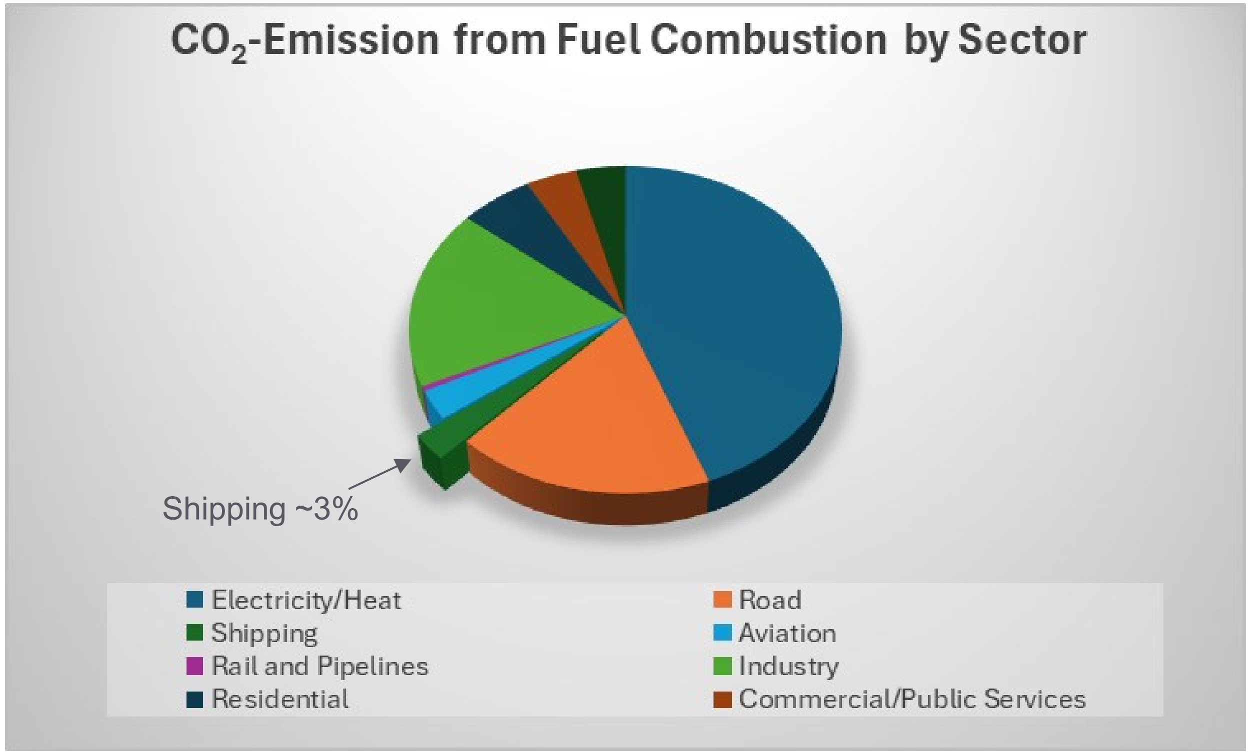
- Substituting fossile energy carriers with non-fossile replacements will require more than one technical solution in order to decarbonize transport for new and existing ships (life-time ~20-30 years) and vehicles (lifetime in EU ~13 years)
- Defossilization of existing vehicle fleet is required as quickly as possible in order to meet 2030's 1.5°GHG-Budget

⇨ **Synthetic low carbon fuels in particular for legacy fleet in transport are crucial**

Global CO_2 Emissions (Combustion) 2023 broken down by sector

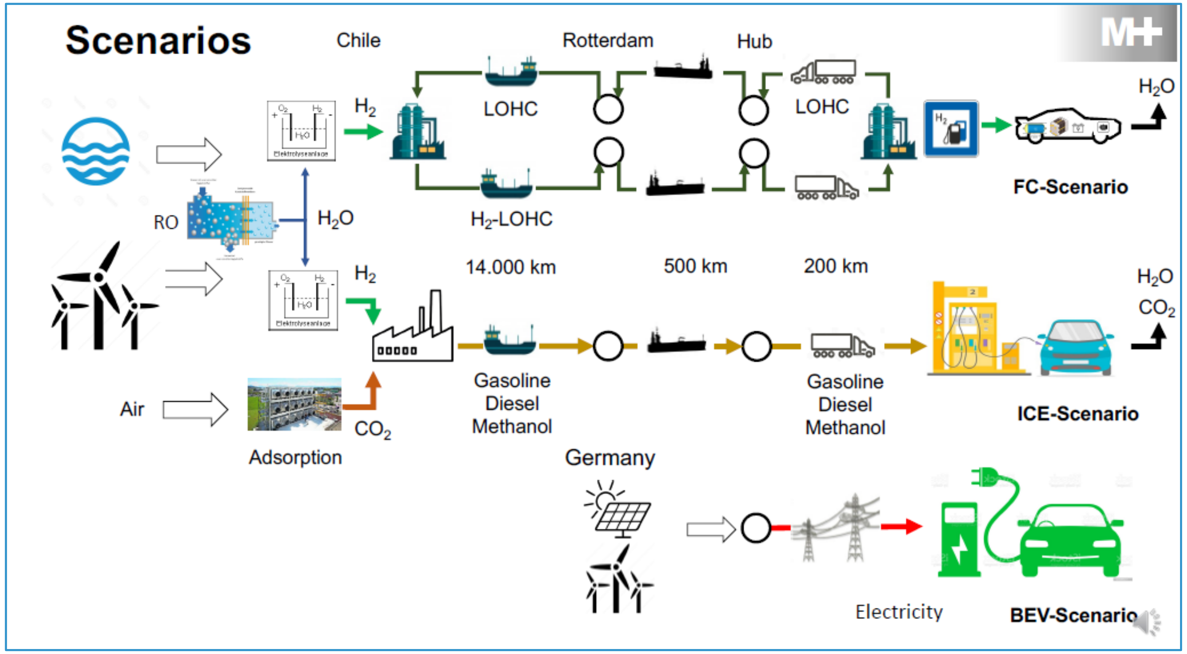


Source: https://www.iea.org/data-and-statistics/data-tools/greenhouse-gas-emissions-from-energy-data-explorer

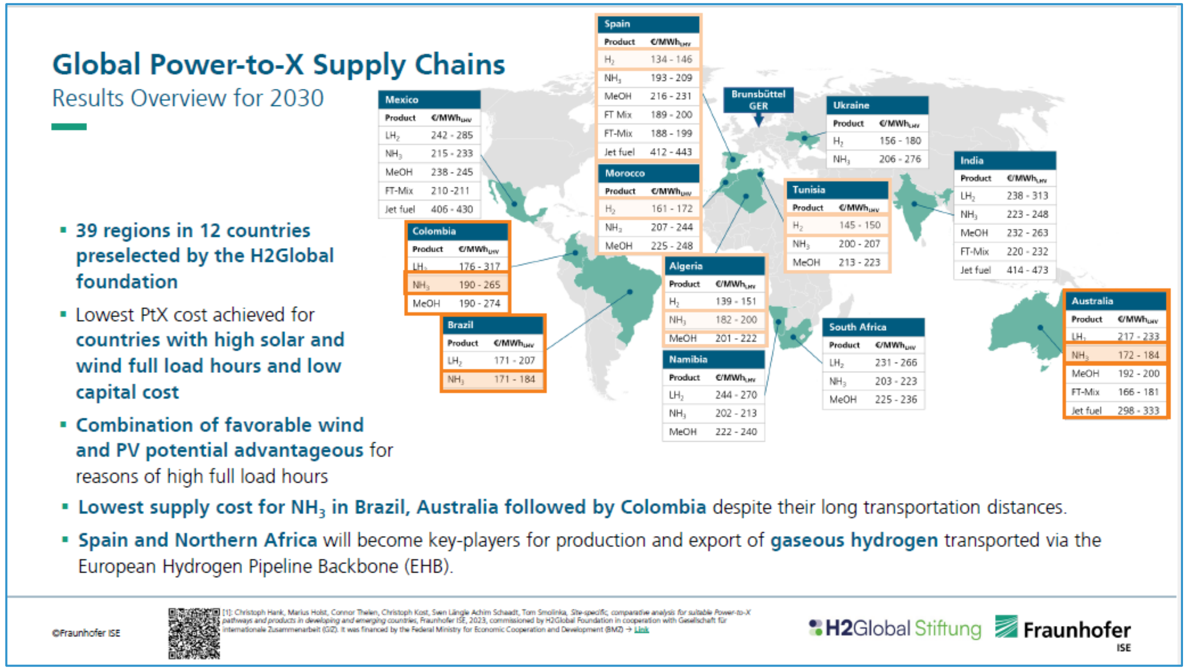


- CO_2 emissions due to fuel combustion about 34,69 Gt_{CO2}
- Transport contributes up to 24 % ➔ Shipping 3 %

Central Role of Shipping in Europe‘s Defossilization



Source: Otto Machhammer -ATZ-Baden-Baden Conference 2021



Source: Robert Szolak-Fraunhofer ISE – DBI Fachforum March 26th in Speyer

- **Shipping will transport renewable energy carriers to Europe from places where it is available (full load hours) and cheap (i.e. South America, Africa, Australia ...)**

Cost structure for marine applications (OPEX)

Cost Component	Typical Share of Total OPEX	Details
Fuel / Energy Costs	30–60%	Includes HFO, MGO, LNG, methanol, DME. CO_2 costs or carbon penalties (EU ETS, IMO future carbon pricing) are included here. Costs vary by fuel type, bunker price, voyage distance.
Crew Costs	10–20%	Salaries, insurance, training, benefits. Varies by flag state and vessel type.
Maintenance / Repairs	5–15%	Engine, hull, safety equipment, periodic drydocking.
Insurance & P&I	2–5%	Hull & machinery insurance; Protection & Indemnity insurance.
Port Charges / Canal Fees	2–5%	Docking, pilotage, pilotage fees, canal tolls (e.g., Suez, Panama).
Stores & Consumables	1–3%	Lubricants, provisions, cleaning, water, spare parts.

- Fuel cost dominate for large vessels, especially if using alternative fuels (methanol, LNG, DME), since these can be 2 – 4 × more expensive than conventional HFO or MGO.
- The trade-off between fuel cost and CO_2 reduction cost is one of the major financial for powertrain selection

Fuels in Marine Applications

Fuel Type	Status	Carbon Neutrality	Key Pros	Key Cons
HFO / MGO	Current	❌ if fossile	Cheap, available	High emissions
LNG	Transition	⚠️ Lower	Cleaner, proven tech	Methane slip
Methanol	Emerging	✅ if green	Liquid, retrofittable	Lower energy density
DME	Emerging	✅ if green	Liquid, retrofittable	Lower energy density
Biofuels (i.e. FAME, HVO)	Transition	✅	Drop-in compatible	Feedstock limits Storage Capable (FAME)
Hydrogen	Future	✅	Zero CO_2	Storage issues, H_2 slip
Ammonia	Future	✅	Carbon-free	Toxicity, handling,conditionally permitted (safety)
Batteries	Niche	✅	Zero emissions	Short range only

International Regulations in Shipping – Emissions/Safety

- **The International Maritime Organization (IMO) - a UN agency - sets the worldwide rules for fuel standards, air pollution, and greenhouse gas (GHG) emissions.**
  - MARPOL Annex VI — “Prevention of Air Pollution from Ships”

- **International Convention for the Prevention of Pollution from Ships (MARPOL), Annex VI: “Prevention of Air Pollution from Ships”**
  - Sulfur content: Global sulfur cap of 0.50% m/m (since Jan 1, 2020). In Emission Control Areas (ECAs): max 0.10%.
  - Permitted fuel (Reg. 18 “Fuel Oil Quality”): Only fuels that meet sulfur and safety standards may be used. Heavy Fuel Oil (HFO) is still allowed if compliant or with scrubbers.
  - Alternative fuels (Reg. 4, 18) LNG, DME, LPG, methanol, biofuels, hydrogen, and ammonia are allowed if they meet safety and emissions requirements

- **In Europe: FuelEU Maritime Regulation and the Alternative Fuels Infrastructure Regulation (AFIR)**
  - Container ships and large passenger ships to use on-shore power supply (or alternative zero-emission technology) when at berth in major EU ports starting from 2030. Completely eliminates exhaust gas emissions while the ship is docked

Regulations in Shipping – GHG Emissions

- **The International Maritime Organization (IMO)**
  - IMO GHG Strategy (adopted in 2018) – GHG **WtW** reduction in the future (20-30% in 2030, 0% in 2050 based on 2008)
  - Target: 5% - 10% to be from zero to near-zero GHG emission fuels in 2030
  - Technical Measures (Tracked)
    - Energy Efficiency Existing Ship Index (EEXI), Carbon Intensity Indicator (CII), Design and operation efficiency requirements
    - **TtW** is currently still in place
  - Carbon pricing will come ➔ 2028 Anticipated ➔ Push for renewable fuels

- **FuelEU Maritime Regulation (2023/1805)**
  - Active since January 2025 – GHG **WtW** reduction (2 % in 2025, 6% in 2030, 31% in 2040, 0% in 2050 based on 2020)
  - Fuels CO_2-reduction is based GHG-emissions factors taken from RED
  - Emission-Trading System (ETS) allowed ➔ buy CO_2 credits generated by overcompensation
  - Fuel penalties will have to be paid in case the ship owner does not meet the CO_2-reduction requirement ➔ cost-factor

Bringing sustainable fuels to the market requires what?

Fuel-Availability

Availability of new fuel

Cooperation

Regulations

- Bring new fuel into European/global Regulations (RED, IMO)

Infrastructure

Develop infrastructure in various forms
From Central hubs up to Filling-station network

Standards

- Initiating supporting activities for standardization or be compatible with existing standards

Standards - What does Standardization mean?

- Standardization refers to the formulation, publication and application of rules, guidelines or characteristics by a recognized organization and its standardization bodies
- Standardization is primarily used when the same or similar objects are used in many different contexts in different places by different groups of people. By establishing and introducing specifications for recurring use, national and international standardization is created within the group of interested parties. This will

    - improve the suitability of products, processes and services for their intended purpose
    - promote the exchange of goods and services and
    - facilitate technical and communicative cooperation.

Standardization is the attempt to standardize products, goods, services and processes

Standards - Types of Standards

- DIN SPEC PAS: Industry specification without genuine standard status. Process via workshops outside the technical committees, subject to a fee, business plan must be available
- DIN TS: Pre-standard (formerly DIN V / DIN SPEC), Standardization process within the technical committees, generally preliminary stage to DIN standard
- DIN: Regular standard
- EN: European Standard, is valid in all CEN-Member-states
  EN must be adopted as National Standard by all CEN-Members
- ISO International Standard (worldwide)
  ISO can be adopted as National Standard (not binding)

Standards for Shipping – ISO 8217:2017

ISO 8217 2017
FUEL STANDARD

ISO 8217 2017 Fuel Standard
for marine distillate fuels

REQUIREMENTS FOR MARINE DISTILLATE FUELS

Characteristic		Unit	Limit	Category ISO-F- DMX	DMA	DFA	DMZ	DFZ	DMB	DFB	Test method(s) and references
Kinematic viscosity at 40 °C		mm^2/s [a]	Max	5,500	6,000		6,000		11,00		ISO 3104
			Min	1,400	2,000		3,000		2,000		
Density at 15 °C		kg/m^3	Max	–	890,0		890,0		900,0		ISO 3675 or ISO 12185; see 6.1
Cetane index		–	Min	45	40		40		35		ISO 4264
Sulfur [b]		mass %	Max	1,00	1,00		1,00		1,50		ISO 8754 or ISO 14596, ASTM D4294; see 6.3
Flash point		°C	Min	43,0	60,0		60,0		60,0		ISO 2719; see 6.4
Hydrogen sulfide		mg/kg	Max	2,00	2,00		2,00		2,00		IP 570; see 6.5
Acid number		mg KOH/g	Max	0,5	0,5		0,5		0,5		ASTM D664; see 6.6
Total sediment by hot filtration		mass %	Max	–	–		–		0,10 [c]		ISO 10307-1; see 6.8
Oxidation stability		g/m^3	Max	25	25		25		25 [d]		ISO 12205
Fatty acid methyl ester (FAME) [e]		volume %	Max	–	–	7,0	–	7,0	–	7,0	ASTM D7963 or IP 579; see 6.10
Carbon residue – Micro method on the 10 % volume distillation residue		mass %	Max	0,30	0,30		0,30		–		ISO 10370
Carbon residue – Micro method		mass %	Max	–	–		–		0,30		ISO 10370
Cloud point [f]	winter	°C	Max	−16	report		report		–		ISO 3015; see 6.11
	summer	°C	Max	−16	–		–		–		
Cold filter plugging point [f]	winter	°C	Max	–	report		report		–		IP 309 or IP 612; see 6.11
	summer	°C	Max	–	–		–		–		
Pour point (upper) [f]	winter	°C	Max	–	−6		−6		0		ISO 3016; see 6.11
	summer	°C	Max	–	0		0		6		
Appearance				Clear and Bright [g]					[c]		see 6.12
Water		volume %	Max	–	–		–		0,30 [c]		ISO 3733
Ash		mass %	Max	0,010	0,010		0,010		0,010		ISO 6245
Lubricity, corrected wear scar diameter (WSD) at 60 °C [h]		µm	Max	520	520		520		520 [d]		ISO 12156-1

Marine Destillates (i.e. DMA =MGO), F=FAME content

ISO 8217 2017
FUEL STANDARD

ISO 8217 2017 Fuel Standard
for marine residual fuels

REQUIREMENTS FOR MARINE RESIDUAL FUELS

Characteristic		Unit	Limit	Category ISO-F- RMA 10	RMB 30	RMD 80	RME 180	RMG 180	RMG 380	RMG 500	RMG 700	RMK 380	RMK 500	RMK 700	Test method reference
Kinematic viscosity at 50 °C		mm^2/s [a]	Max	10,00	30,00	80,00	180,0	180,0	380,0	500,0	700,0	380,0	500,0	700,0	ISO 3104
Density at 15 °C		kg/m^3	Max	920,0	960,0	975,0	991,0	991,0				1010,0			ISO 3675 or ISO 12185; see 6.1
CCAI		–	Max	850	860	860	860	870				870			see 6.2
Sulfur [b]		mass %	Max	Statutory requirements											ISO 8754 or ISO 14596 or ASTM D4294; see 6.3
Flash point		°C	Min	60,0	60,0	60,0	60,0	60,0				60,0			ISO 2719; see 6.4
Hydrogen sulfide		mg/kg	Max	2,00	2,00	2,00	2,00	2,00				2,00			IP 570; see 6.5
Acid number [c]		mg KOH/g	Max	2,5	2,5	2,5	2,5	2,5				2,5			ASTM D664; see 6.6
Total sediment – Aged		mass %	Max	0,10	0,10	0,10	0,10	0,10				0,10			ISO 10307-2; see 6.9
Carbon residue – Micro method		mass %	Max	2,50	10,00	14,00	15,00	18,00				20,00			ISO 10370
Pour point (upper) [d]	winter	°C	Max	0	0	30	30	30				30			ISO 3016
	summer	°C	Max	6	6	30	30	30				30			
Water		volume %	Max	0,30	0,50	0,50	0,50	0,50				0,50			ISO 3733
Ash		mass %	Max	0,040	0,070	0,070	0,070	0,100				0,150			ISO 6245
Vanadium		mg/kg	Max	50	150	150	150	350				450			IP 501, IP 470 or ISO 14597; see 6.14
Sodium		mg/kg	Max	50	100	100	50	100				100			IP 501, IP 470; see 6.15
Aluminium plus silicon		mg/kg	Max	25	40	40	50	60				60			IP 501, IP 470 or ISO 10478; see 6.16
Used lubricating oil (ULO): – Calcium and zinc; or – Calcium and phosphorus		mg/kg	–	Calcium > 30 and zinc > 15 or Calcium > 30 and phosphorus > 15											IP 501 or IP 470, IP 500; see 6.17

Marine Residuals (different viscosities)

- The scope of the standard is expanded to explicitly include fuels from synthetic, renewable, or recycled sources. The 2024 version states the fuel may be hydrocarbons from petroleum, or synthetic/renewable hydrocarbons, or blends thereof. ➔ more flexible blending

Methanol – Standardization for Ships & On-/Offroad

Marine-Applications at ISO/TC 28/SC 4
Convenor: Monique Vermeire, Chevron

On- and Off-road Applications (Non-Marine-Applications)
at NA 062-06-32-09 AK
Convenor: Werner Willems, Tec4Fuels

ISO

DRAFT
International Standard

ISO/DIS 6583

Specification of methanol as a fuel for marine applications

Spécification du méthanol comme carburant pour les applications marines

ICS: 75.160.20

ISO/TC **28**/SC **4**
Secretariat: **AFNOR**
Voting begins on:
2024-02-14
Voting terminates on:
2024-05-08

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Reference number
ISO/DIS 6583:2024(en)

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DIN-TS 51697 Draft

Spezifikation von Methanol als Kraftstoff für On/Offroad-Anwendungen

Specification of methanol as a fuel for On- and Offroad applications

Spécification du méthanol comme carburant pour les applications routières et hors-route

- 26 Experts across the entire value chain from Germany + 3 guests from SIS (Standardization organization sweden) meet to develop a DIN TS specification
- The aim is to define a DIN standard once measurement methods have been developed and validated
- ISO 6583 released in 2024, DIN/TS 51697 will be release early 2026

Example: Methanol – Specification On-/Off-Road

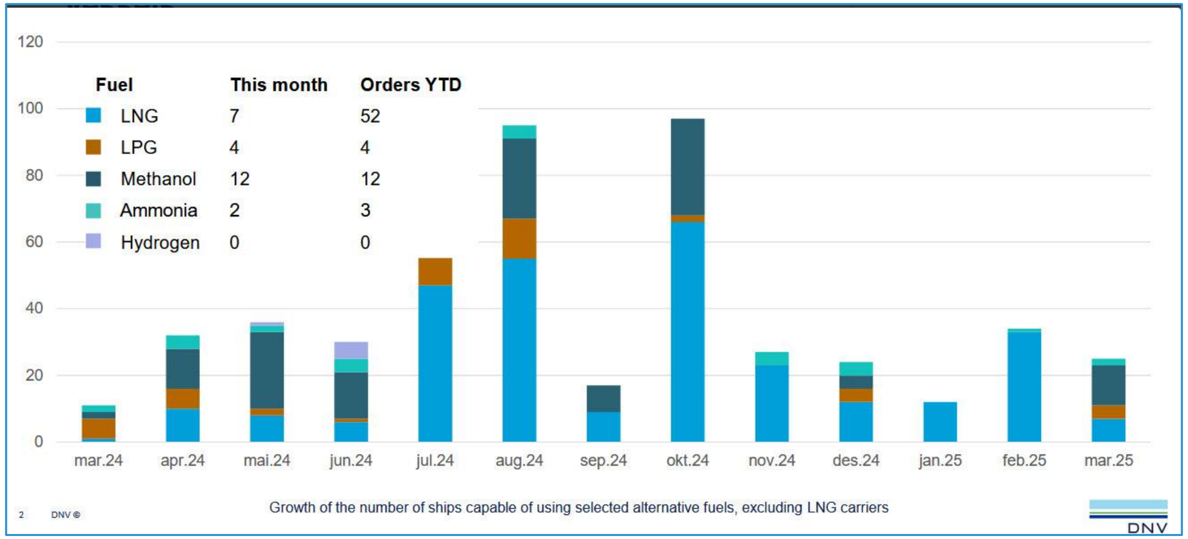
Characteristics	Units	Limit	MA	MB	Test method(s) and references
General requirements			Clauses 5 to 7		
Appearance			Homogenous, clear and free of suspended matter		IMPCA 003 /DIN EN 15769
Methanol content by mass on dry basis	%	min.	99,85	99,85	[b]
Impurities content by mass on dry basis [c]	%	max.	0,15	0,15	IMPCA 001/DIN EN 15721 (mod.)
Ethanol content by mass on dry basis	mg/kg	max.	50	50	IMPCA 001-14/ DIN EN 15721 (mod.) [f]
Water content by mass	%	max.	0,500	0,500	ASTM E1064/DIN EN 15489 (mod.)
Acetone content by mass	mg/kg	max.	30	30	IMPCA 001-14/ DIN EN 15721 (mod.) [f]
Density at 15° C	kg/m3	min.	795,0	795,0	DIN ISO 12185 ; see 6.2
		max.	797,0	797,0	
Chloride content al Cl[e]	mg/kg	max.	0,5	0,5	DIN EN 15492 (mod.)[f]
Sulfatgehalt	mg/kg	max.	Tbd	Tbd	DIN EN 15492 (mod.)[f]
Formiatgehalt	mg/kg	max	Tbd	Tbd	DIN EN 15492 (mod.)[f]
Sulfur content	mg/kg	max.	5	0,5	DIN EN ISO 20846/ DIN EN 15486 ; see 6.3
Acidity as acetic acid	mg/kg	max.	30	30	DIN EN 15491
Lubricity (bei 25° C)			tbd	–	DIN EN ISO 12156-1 (mod.)[f]
Particle count			tbd	tbd	ASTM D7619/ISO 4406
Lower Heating Value	MJ/kg	min	tbd	-	Berechnung nach Annex B
Colour		max.	5	5	DIN EN ISO 6271
Elemente mittels ICP (Cu, Zn, Al, Fe, Na, K,Ca, Mg,P)	mg/kg	max	tbd	tbd	DIN EN 15837 (mod.)[f]

Snapshot of alternative fuel related activities in 2025

News related to Methanol Applications

Led by Tsuneishi Shipbuilding Co., Ltd. and the Mærsk Mc-Kinney Møller Center for Zero Carbon Shipping, the retrofit project establishes a model that could pave the way for medium size bulk carriers to decarbonize, shedding light onto the various factors that must be considered when retrofitting.

Methanol Tops March Orders for Alternative Fueled Vessels



Methanol vs. Ammonia – What is the better option?

- Europe is pushing for Hydrogen economy
- Green Hydrogen needs to be imported in order to satisfy the required demands
- Methanol, Ammonia and DME have higher hydrogen content than liquified Hydrogen itself (40-50% more)

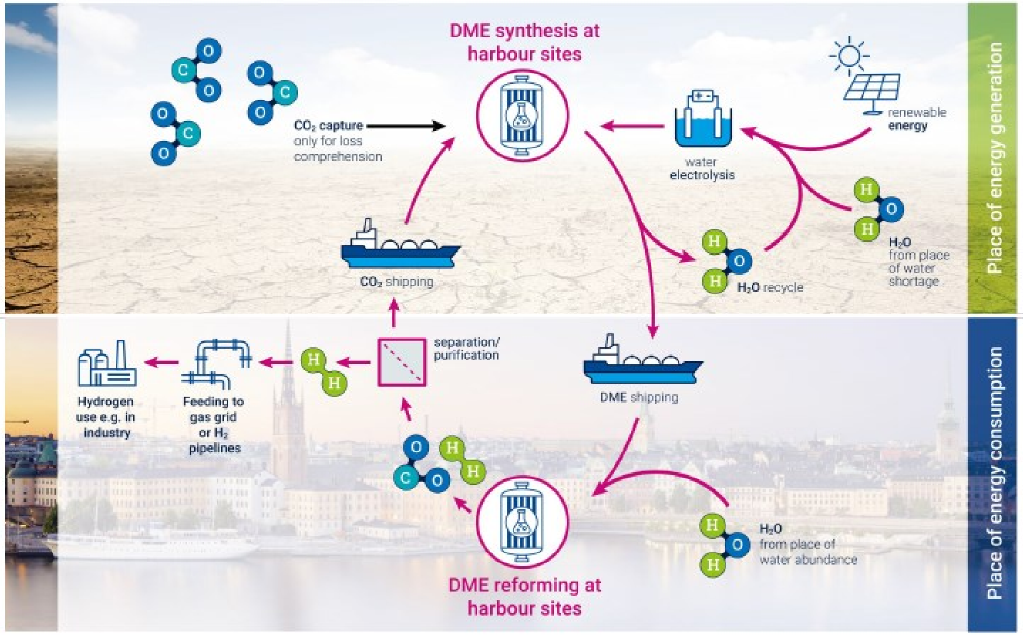
Fuel	Permitted?	Regulation	Notes
Methanol	✅ Yes	IGF Code + MSC.1/Circ.1621	Fully permitted, detailed safety code exists
Ammonia	⚠️ Conditionally Yes	IGF Code (alt. design) + MSC.1/Circ.1647	Allowed with flag-state approval until full code adoption
Both	✅	MARPOL Annex VI	Must meet emissions & quality limits
In EU	✅	FuelEU Maritime + RED III	Recognized as low-carbon/e-fuels

DME - Future Fuel for Marine Applications

DME as hydrogen vector

The DME / CO_2 cycle

- At reforming location: Efficient capture of concentrated CO_2 and back-shipping to synthesis location
- Same ship for DME and CO_2 transport
- DAC only required for loss compensation
- At energy exporting country: DME synthesis from CO_2 and "fresh" H_2
  - generates H_2O as byproduct → 50 % reduced water demand



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Schühle, P.; Stöber, R.; Gierse, M.; Schaadt, A.; Szolak, R.; Thill, S.; Alders, M.; Hebling, C.; Wasserscheid, P.; Salem, O. (2023) Dimethyl ether/CO_2 - a hitherto underestimated H_2 storage cycle; submitted to Energy & Environmental Science.

Fraunhofer ISE

Source: Rober Szolak-Fraunhofer ISE – DBI Fachforum March 26th in Speyer

DME - Future Fuel for Marine Applications

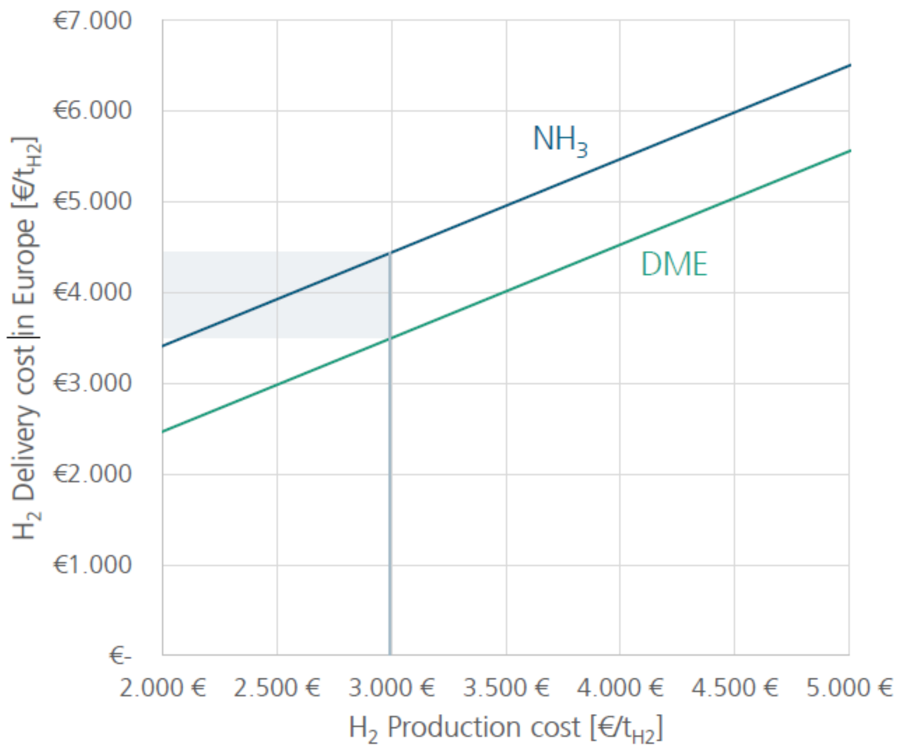
DME as hydrogen vector

Cost Estimation

Simplified techno economic analysis:

- Cost of delivery of 1 ton of H_2 at the point of utilization as a function of H_2 production cost
- Delivery cost of H_2 by shipping with tanker over 20,000 km distance
- CO_2 DAC cost at 720 €/t
- N_2 cost at 200 €/t

→ **DME allows cheaper H_2 delivery than NH_3**



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Schühle, P.; Stöber, R.; Semmel, M.; Schaadt, A.; Szolak, R.; Thill, S.; Alders, M.; Hebling, C.; Wasserscheid, P.; Salem, O. (2023) Dimethyl ether/CO_2 - a hitherto underestimated H_2 storage cycle; submitted to Energy & Environmental Science.

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Conclusion

- **In marine applications, renewable fuels are key to reducing greenhouse gases, as they provide high energy density while reducing CO_2 emissions at the same time**
- **International regulations (e.g. FuelEU Maritime, the IMO GHG Strategy..) have been/are being/will be developed to guarantee global CO_2 reduction favorized on a well-to-wake basis, taking into account both fuel production and utilization.**
- **To guarantee sufficient fuel quality, it is important to have fuel standards in place to ensure comparability, accountability, safety and technical compatibility.**
- **To reduce CO_2 emissions in the shipping industry, alternative fuels such as renewable drop-in components compatible with fossil fuels, and renewable fuels such as ammonia and methanol, are gaining more traction as they will have a greater impact on the total cost of marine transport worldwide.**
- **Marine transport will play a central role in the shipment of renewable energy carriers to places where it is not available. Here DME as hydrogen carrier is a promising solution**

Thank you for your attention!

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