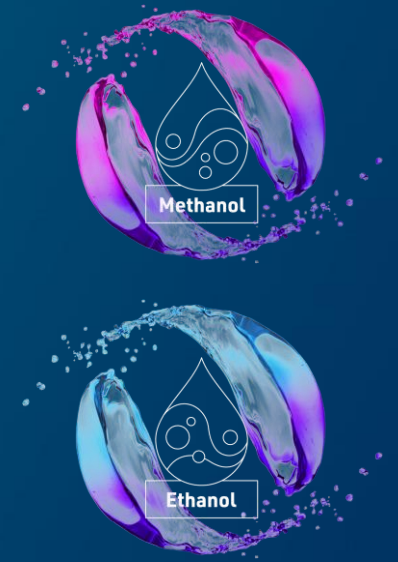
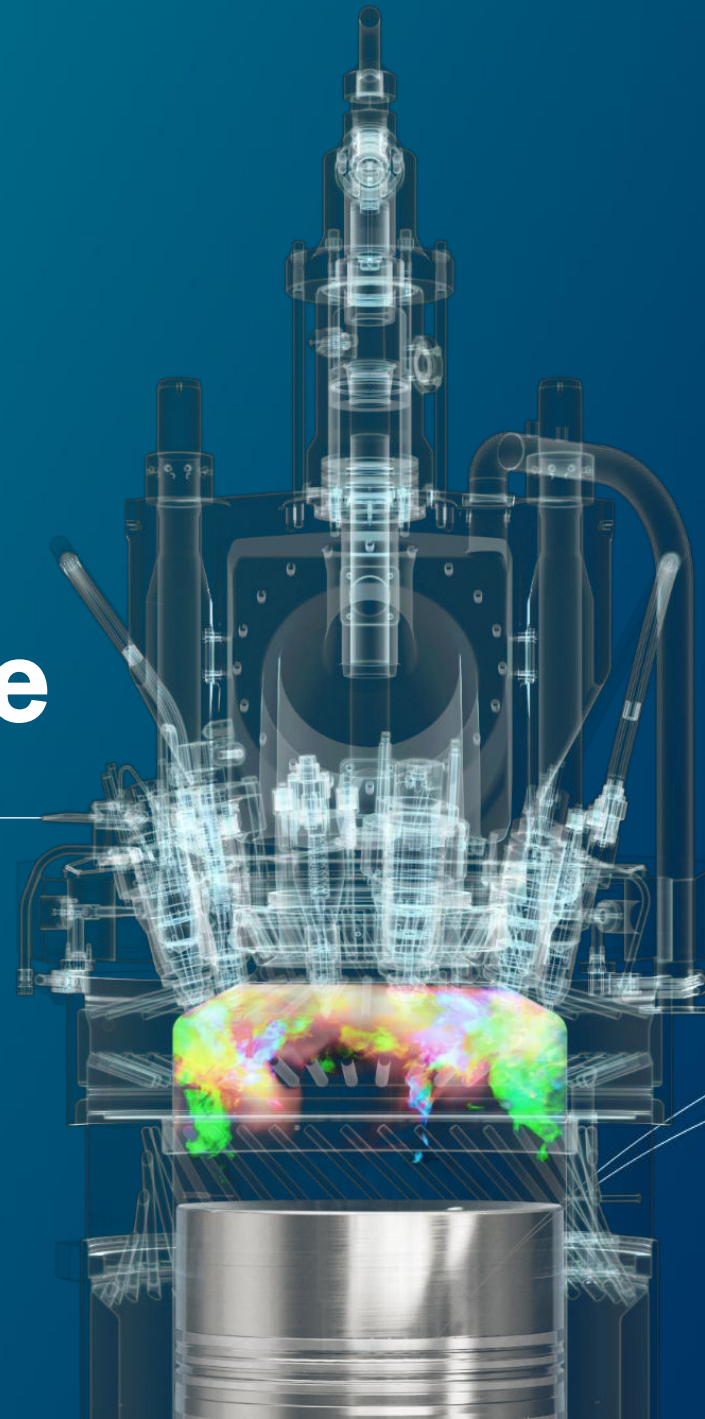


X-DFM

by WinGD

WinGD Dual-fuel Methanol-Ethanol Engine

Status Update – September, 2026

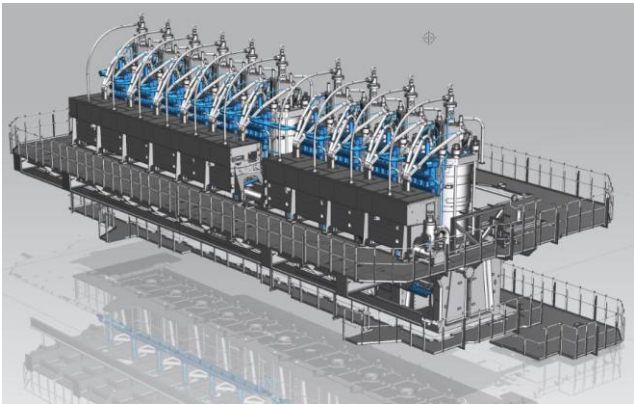


WINGD

References, Methanol

Large range of engine types contracted for different vessel types

Engine type	# of sets	Ship types
X92DF-M-1.0	41	UL Container vessels
X82DF-M-1.0	22 (2 ethanol enabled)	Intermediate CV, VLOC, VLCC
X72DF-M-1.0	4 (4 ethanol enabled)	VLOC
X62DF-M-1.0	11	Aframax tankers
X62DF-M-S1.0	6	Container vessels
X52DF-M-S1.0	5	2000 CEU PCTC, Tankers
Total	89 sets	



PRESS RELEASE

WinGD to supply methanol-fuelled engines for six green container vessels

Series marine power company WinGD will supply X-DFM methanol-fuelled engines for a series of six container vessels to be built at Yangzijiang Shipbuilding in China. The 9,000 TEU vessels will each be powered by an X92DF-M engine built by HD Hyundai Heavy Industries Engine & Machinery Division (HHI EMD), to be delivered in August 2025.

The new order, which includes options for further engines, expands WinGD's methanol engine orders into the 82,000 TEU size. As announced previously, early interest in the X92DF-M resulted in an order for four engines to power ultra-large container vessels being built for COSCO SHIPPING LINC.

Volkmar Gahle, Director Sales, WinGD, said: "This order confirms that our X-DFM engines will be in service long before green methanol is widely available and before regulatory requirements come into force, giving operators time to build experience with the new fuel and engines. We are delighted that one of the biggest and most influential container lines has also invested in our X-DFM technology, sending a strong signal to all operators currently making their own alternative fuel decisions."

As previously stated, both X-DFM and ammonia-fuelled X-DFM-A engines will be available for delivery from Q1 2025. The combustion principle and engine platform deployed for X-DFM engines is based on the latest X-Engines from WinGD, supplemented by high-pressure methanol injection. X-Engines, including the highly efficient X92-B and X82-2-D engine, already power many of the world's biggest container ships.

Notable features of X-DFM engines include comparable performance with X-Engines in both methanol and diesel modes, low pilot fuel requirements achieved through precisely controlled common rail injection, and NOx Tier III compliance in both modes with selective catalytic reduction. The new engine concept will be retrofitable to the X-Engine series as soon as X-DFM engines are available in the relevant bore sizes.

The new vessel series will enter service in 2026 and 2027.

WinGD

methanol engines for COSCO liner vessels

Fuelled engines for four 18,000 TEU container vessels to be built by Yangzijiang Shipbuilding (Yangzhou) Co., Ltd. These vessels will be WinGD's first X92DF-M engines in China. This ground-breaking is attended by the collaboration partners from COSCO and engine builder CSSC CMD in Shanghai, which is jointly building the first vessel in the series to be the first to have methanol-ready engines. Earlier vessels will initially have methanol-ready X82-B engines prior to entering service.

Methanol-fuelled container vessels to be built in China and WinGD's green transformation strategy.

Leading container owners including COSCO SHIPPING Lines, MSC and CMA CGM. The reliability and efficiency of the X92-B will translate directly to the X92DF-M, which will utilize the same high-pressure Diesel combustion cycle.

The order enables WinGD to advance its timeline for developing conversion packages for methanol-fuelled engines. WinGD will introduce a methanol package for the X92-B engine as soon as the fourth vessel in the series is delivered - opening the market for existing vessels with X92-B engines to be converted to use the carbon-neutral fuel.



Owners include:

- COSCO Shipping Lines
- COSCO Shipping Bulk
- COSCO Shipping Energy

- Maersk
- ONE
- Seaspan
- Evergreen



10X92DF-M-1.0

Test Results



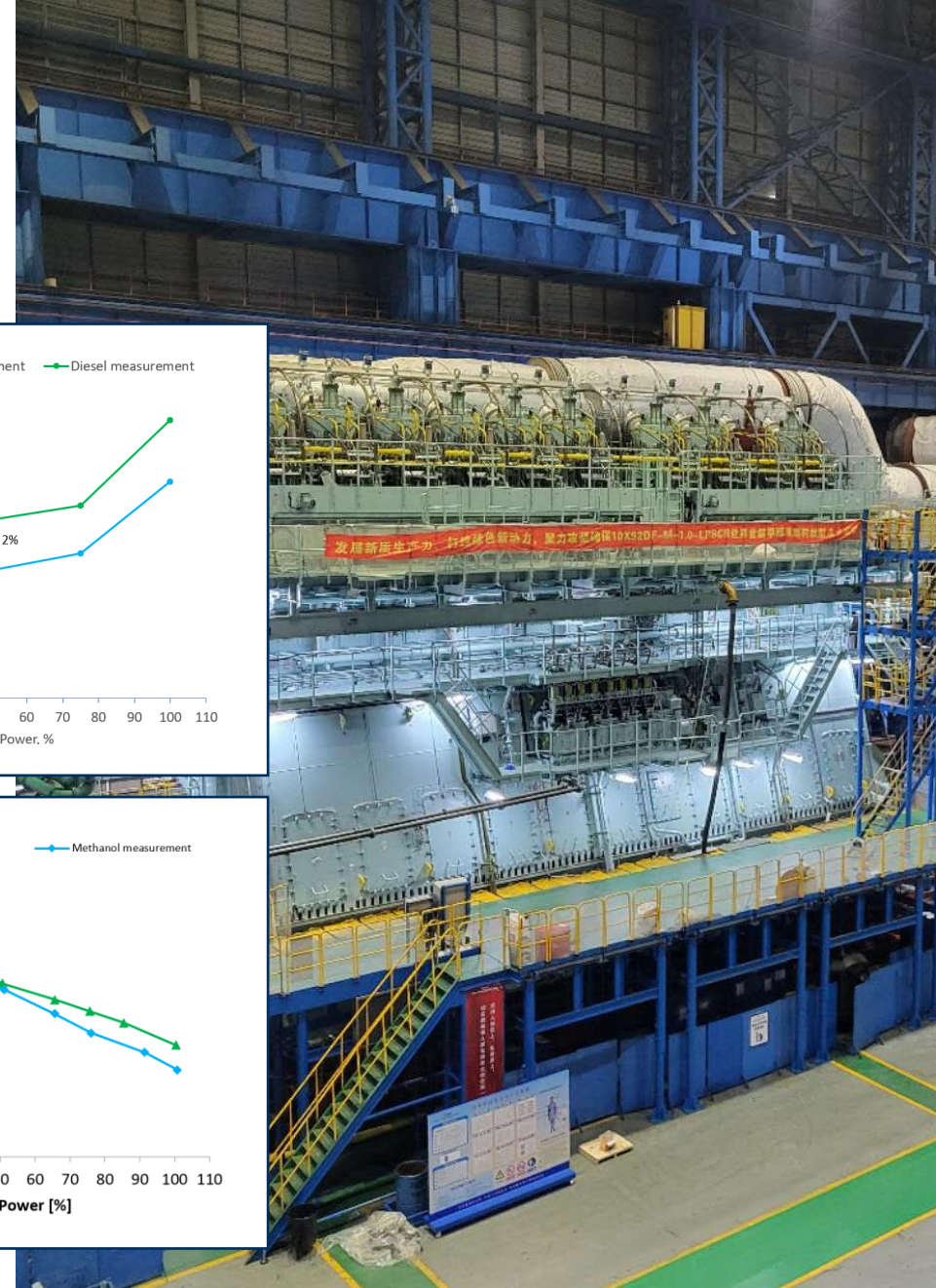
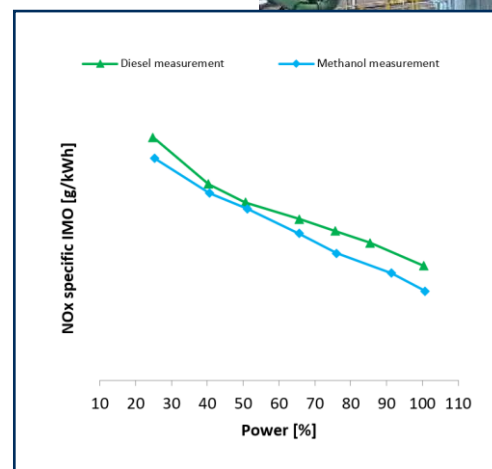
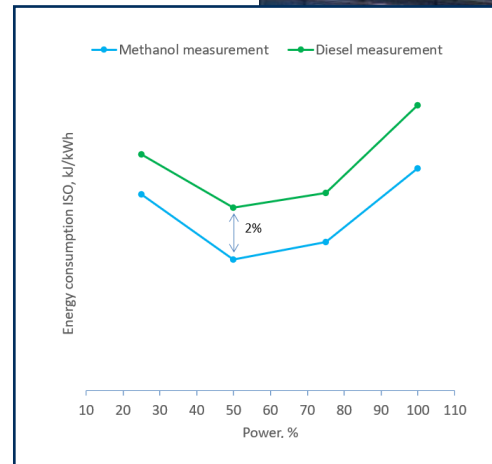
Consumption

- Best in class fuel consumption and methanol 2% lower than Diesel
- Pilot energy share <5% @100% load is been achieved



Emissions:

- NO_x compliant with Tier II and Tier III standards, also for upcoming regulations for multiple fuel use
- CO₂ ca. 7.5% lower than in Diesel mode
- CH₂OH (formaldehyde) well below 25ppm
- HCN below well below 15ppm



10X92DF-M

Methanol Sea Trial Milestone



Successful Sea Trial Completed on 10 June 2025



Conducted by COSCO Yangzhou SY, CMD and WinGD



The engine passed all inspection items in one round



The sea trials successfully demonstrated the integration of the engine and the fuel supply system ensuring robust safety levels

X92DF-M-1.0 – Piston Running

Good performance experienced in service



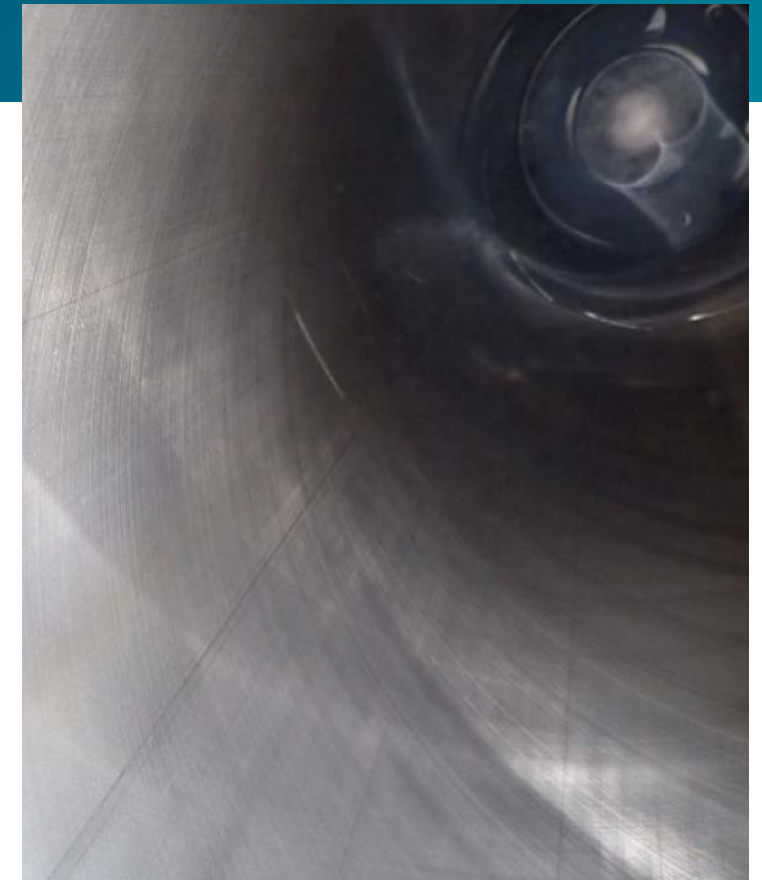
- Clean ring pack
- Contact surface well distributed

Example 1 after 1'111 h:

- Unit #3
- MeOH running hours: 23h
- Engine load: 40 – 50%
- S content: 0.5 %
- Feed rate: 1.15 g/kWh



Top piston ring in good condition

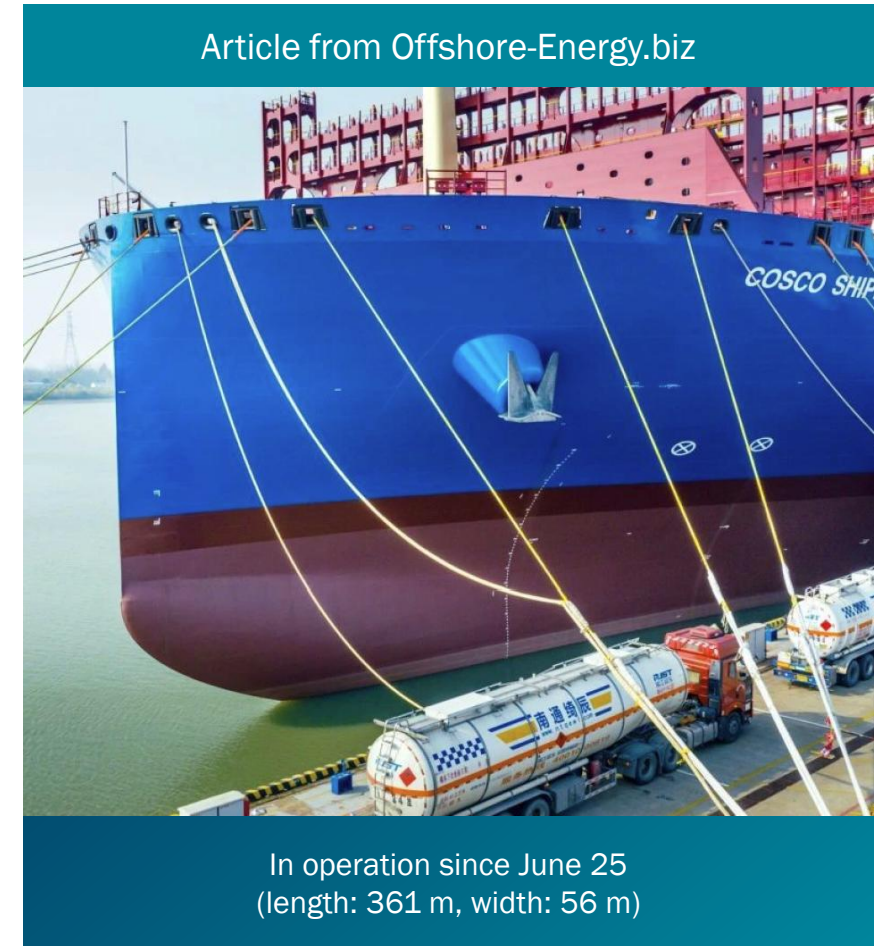


Liner with honing marks visible

Experience from field follow-up

Summary 10X92DF-M-1.0

- 1 3 engines already in operation – Two engines retrofitted before delivery
- 2 Methanol performance in service is similar as the shop test
- 3 Methanol can be used for steady operation as long as needed
- 4 A 12-hours of endurance run was done with no issue at all
- 5 Not much of long-term methanol operation in service (2 hours per week) only due to the cost consideration from the ship operator
- 6 Some smaller issues have been noted without affecting the sailing schedule, e.g.:
 - Methanol leakage of few ppm in the double wall pipe without risk for the crew
 - Leakage on main fuel diesel injector and a new material will be tested
- 7 Piston running behaviour is good and regularly checked and monitored
 - Possibility to reduce the cylinder oil lubrication feed rate
- 8 Operation of the vessels is closely followed-up to support the crew onboard



Ethanol: Leveraging the Proven X-DF-M Platform

Development & Market Entry Roadmap

Ethanol solution derived from the X-DF-M methanol engine



Minimal technical adaptation required



First order secured in May 2026 (Vale)



First installations from 2027



X-DF Methanol/Ethanol Engines

X52DF-M-S1.0

IMO Tier II & Tier III (SCR)

Cylinder bore	520 mm
Piston stroke	2 045 mm
Speed	80-120 rpm
Mean effective pressure at R1	22.0 bar
Stroke / bore	3.93

RATED POWER, PRINCIPAL DIMENSIONS AND MASS

Cyl.	Output in kW at				Length A mm	Length A' mm	Dry mass tonnes
	120 rpm	80 rpm	R3	R4			
5	R1	R2	R3	R4	5 485	6 565	200
6	11 440	8 220	7 680	5 440	6 345	7 415	224
7	13 370	9 590	8 940	6 370	7 205		257
8	15 280	10 940	10 240	7 280	8 065		287
				B	C	D	D (ISCR)
Dimensions (mm)				3 100	1 185	7 775	8 000
				F1	F2	F3	G
				9 340	9 340	8 800	1 675

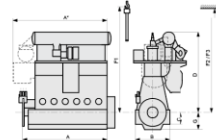
BRAKE SPECIFIC FUEL CONSUMPTION IN METHANOL/ETHANOL MODE

Rating point	R1	R2	R3	R4
BSEC (energy)	6 897 / 7 038	6 645 / 6 782	6 940 / 7 081	6 855 / 6 995
BSEC (gas)	329.2 / 248.8	316.6 / 239.8	331.4 / 250.3	327.1 / 247.3
BSPC (pilot fuel)	g/kWh	8.1 / 8.7	8.1 / 8.3	8.1 / 8.7

BRAKE SPECIFIC FUEL CONSUMPTION IN DIESEL MODE

Rating point	R1	R2	R3	R4
BSFC (diesel Tier II)	g/kWh	164.8	158.8	165.8

For definitions see page 44.
ISCR available for
5- to 7-cylinder engines
with one TC on
exhaust side



50

PRESS RELEASE

WINGD

WinGD to introduce first ethanol-fuelled marine two-stroke engine in 2026

Swiss marine power company WinGD will offer the first ethanol-fuelled two-stroke marine engine next year, with deliveries for newbuild and retrofit applications starting in 2027. The announcement follows a decade of investigation into ethanol fuel—including full-scale engine tests in 2018—and the successful launch of a methanol-fuelled engine that uses the same combustion concept and is subject to the same safety regulations as the new ethanol engine.

The new engine will be adapted from the X-DF-M methanol-fuelled engine, which has received strong feedback from first users and class societies approving the design. The diesel-cycle concept—available across the full range of bore sizes currently offered by WinGD—will feature an adapted control system and fuel injector nozzle arrangement to account for the higher energy density of ethanol and the consequently lower fuel volumes required.

WinGD has been studying ethanol fuel, which has a similar combustion and emissions profile to methanol, since 2014 beginning with a project financed by the Swiss Federal Office of Energy. WinGD later led work to develop a flexible injector for alcohol fuels as part of the EU-funded HERCULES 2 project starting in 2016. Ethanol can be produced renewably from biomass and is prevalent at a competitive price in some national markets, driving interest in the new fuel.

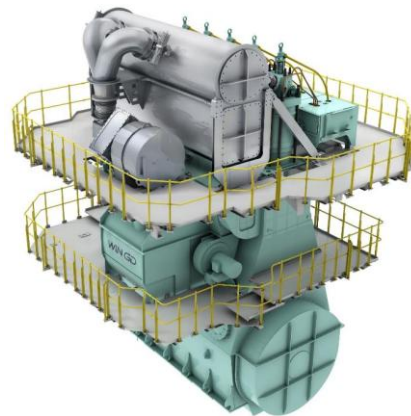
WinGD VP R&D Sebastian Hensel said: "This announcement is further evidence of the strength of our research programme. Our early ethanol explorations were crucial to the successful development of our X-DF-M methanol engine, and now both are enabling the rapid commercialisation of the first ethanol-fuelled two-stroke engine. As global emission regulations are set to be passed, we're pleased to be able to offer a further lower carbon alternative to ship owners and operators."

WinGD is in discussions with several ship owners, ethanol fuel suppliers and class societies about the first commercial applications of its ethanol engine—and will confirm at a later date whether the engine will be optimised for ethanol or optimised for methanol with secondary ethanol capability. WinGD also recently became a founding member of the Global Ethanol Association in an effort to connect key enablers in the ethanol value chain.

Hensel concluded: "With our long experience of and deep commitment to developing ethanol as a marine fuel, ship owners can be confident that we will deliver an engine design with similar robust performance, efficiency and reliability as WinGD's existing dual-fuel engine portfolio."

Further details will be made available in WinGD's Low-Speed Engines Booklet in early 2026.

ENDS



Ethanol as fuel

Summary

WinGD confirms similar combustion, performance, and emissions for both fuels



Comparable characteristics
→ same design & safety considerations



IMO MSC.1/Circ.1621 applies to both methanol and ethanol



Fuel storage & supply system (FSS) requirements are valid for both



Ethanol's higher LHV → lower flow rate

- FSS adjustment
- Injection system must account for different fuel quantities



Fig. 1 – Ethanol tests at ERIC (Switzerland): RTX-6 engine, Test rig, and Spray Combustion Chamber with lab scale prototypes

General Properties

Compatibility of Ethanol for the Methanol Injection System



Generally, methanol and ethanol are both alcohol-based fuels and are therefore similar in their properties



Due to the difference in LHV, the injected volume/mass of ethanol is approx. 25% smaller than methanol



The injection system is designed to cover the necessary amount of methanol at full load, thus fully covers ethanol operation



The minimum injection amount may lead to slightly higher minimum power in ethanol mode

Properties	Unit	Ethanol	Methanol	Marine gas oil
Flash point	°C	9-11	10 - 12	60
Density	kg/m ³	789 (at 20 °C)	790 (at 20 °C)	890 (at 15 °C)
Lower Heating Value (LHV)	MJ/kg	26.8	19.9	42.7
Relative volume per energy content	-	1.8	2.5	1
Boiling point	°C	78.5	64.7	150 - 380
Explosive limit in air	%(vol)	3-19	6 - 36	1 - 6
Solubility: Methanol in water/water in methanol	%	100/100	100/100	NA

Ethanol as fuel

Spray Combustion & Test Engine Results vs diesel

Methanol & ethanol spray propagation $\approx$ Diesel



Longer ignition delay $\rightarrow$ pilot injection required



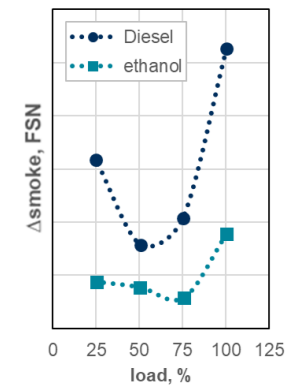
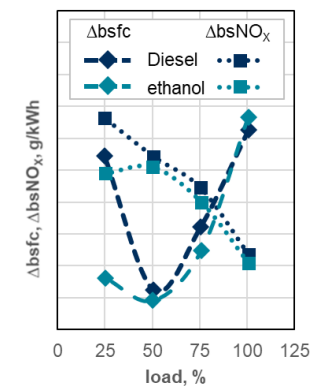
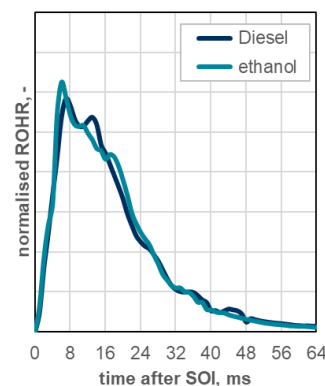
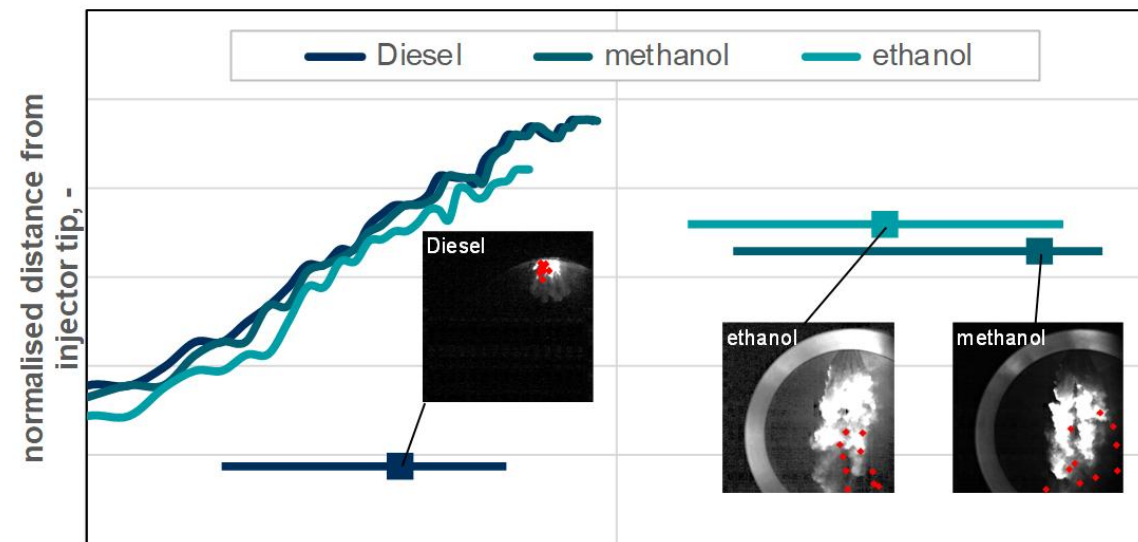
Similar ROHR at full load



Better BSFC & NO_x across load range

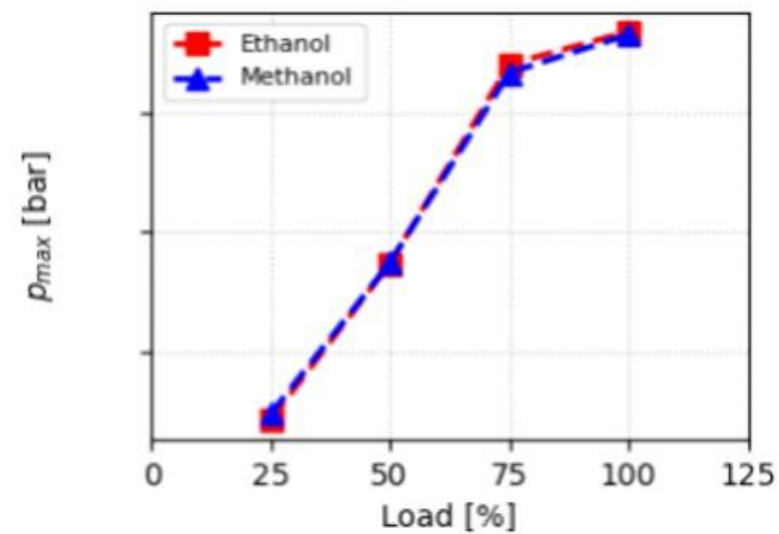
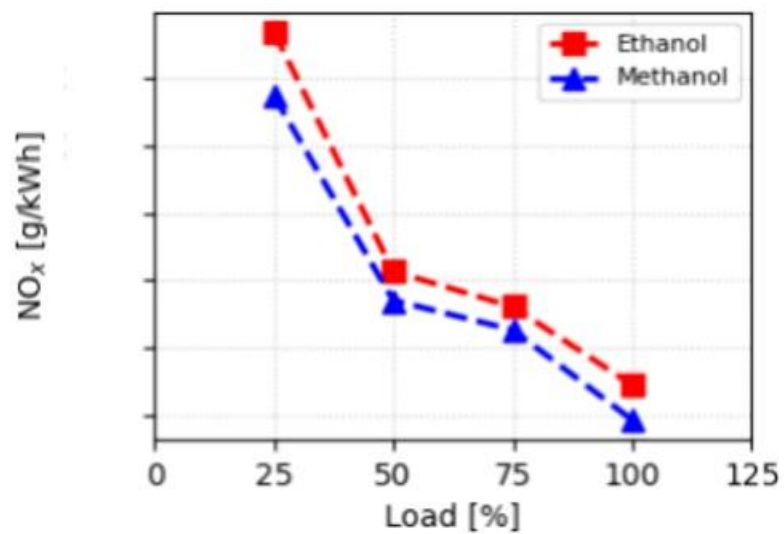
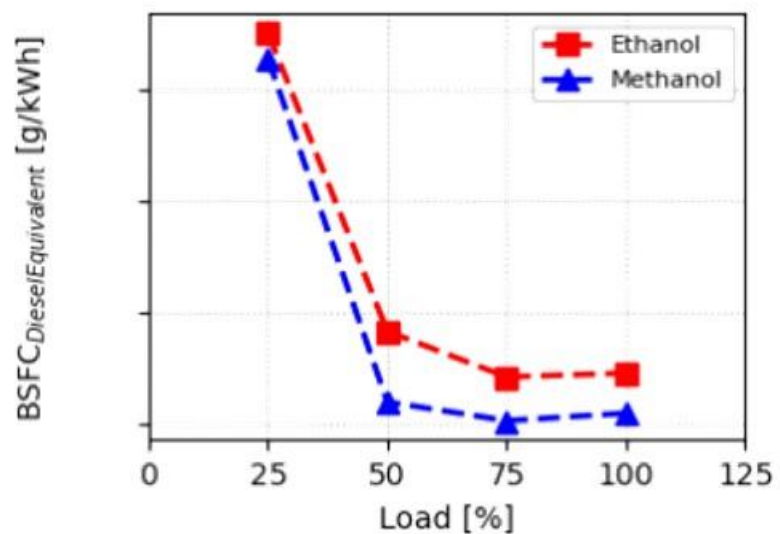


Better smoke emissions with ethanol & adapted combustion system



Performance

Test results

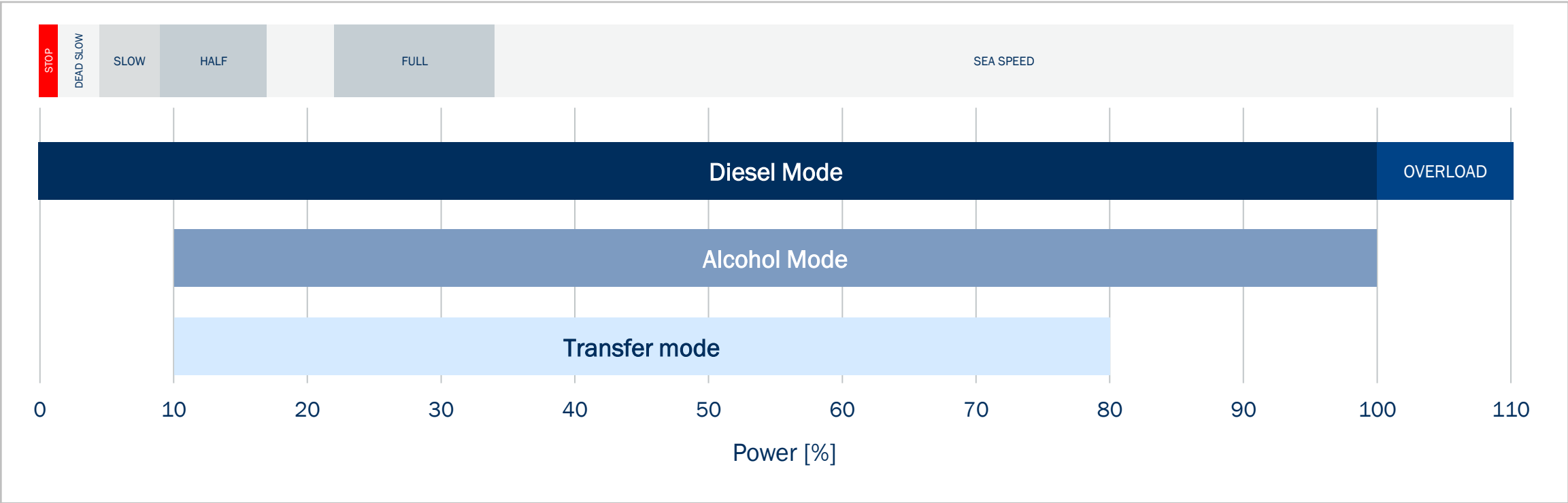


CONFIDENTIAL

Engine Operation Modes



No additional operating mode for ethanol foreseen.
The engine can operate on methanol or ethanol or any blend of the two alcohols in alcohol mode



Ethanol Technology development

Latest X-DF-M engine as basis - Scope of changes compared to methanol

Engine modifications

- The methanol fuel injection system is used for ethanol with only minor adaptations, additional sensors, gas leakage detection sensors, engine control software and tuning parameters.

Methanol - ethanol fuel supply system

- The same fuel supply system and fuel tanks can be used for both methanol and ethanol.
- The differences between the two alcohols must be considered in the design of the fuel supply system, mainly the difference in Lower Heating Value (LHV), resulting in different fuel consumption and flows, and the difference in explosive limit in air for gas leakage detection.

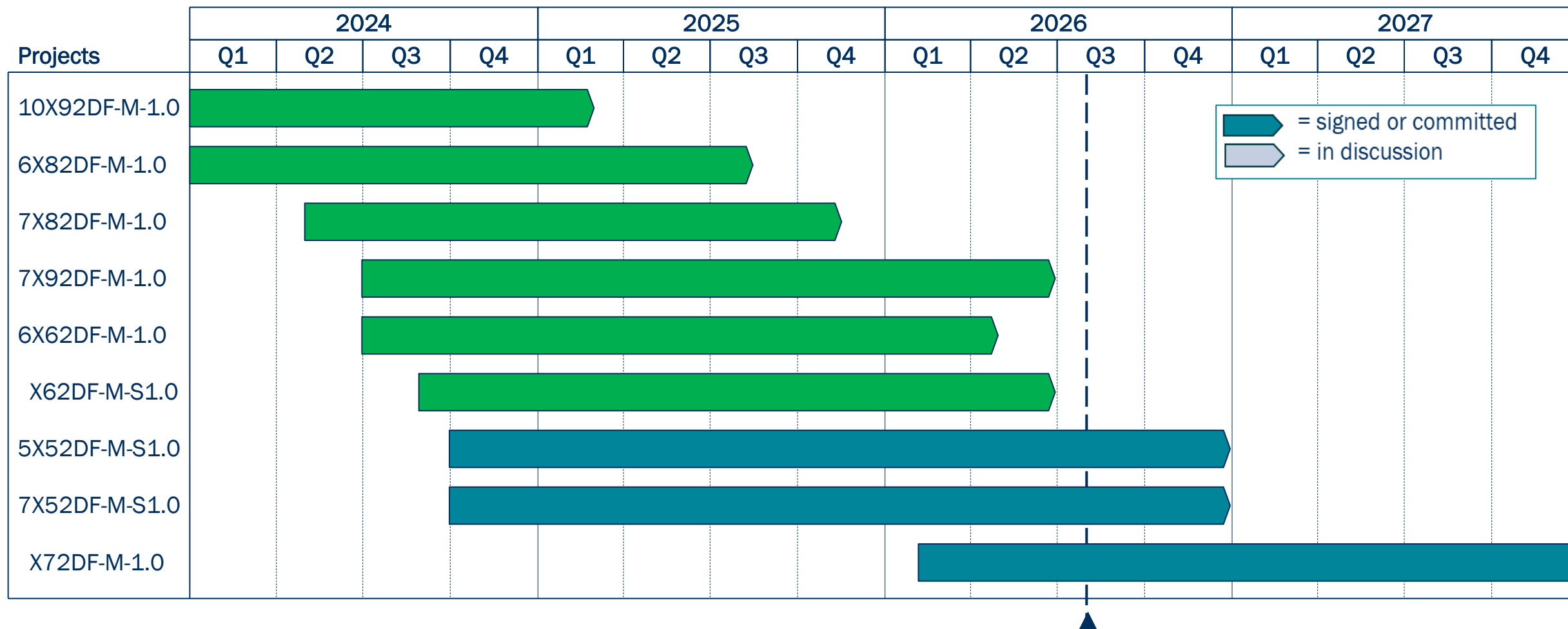
Ethanol Technology development

Available options for the X-DF-M engines

The following options are available for the tuning and certification of the engine:

1. **Methanol only** – optimised for methanol resulting in 2% lower energy consumption compared to diesel mode. Performance data available in GTD
 2. **Ethanol only** – optimised for ethanol with similar energy consumption like diesel mode. Performance data available on request.
 3. **Ethanol or methanol - including any blends of the two alcohols** – optimised for ethanol and certified for both alcohols and any blend ratio of the two alcohols. There is an expected methanol fuel energy consumption penalty of 1 - 2%, compared to the methanol optimised option 1, i.e. same energy consumption on methanol, ethanol and diesel fuels. Performance data available on request
- Testing of ethanol and methanol blends during the FAT and relevant costs must be agreed separately with the customer and the classification society.
 - NOx EIAPP certification to be done with diesel and ethanol for option 2 & 3
 - The diesel mode remains unchanged – The methanol/ethanol mode will be tuned to a NOx level below diesel.

Methanol Technology Rollout



Note: The arrows represent delivery of first engine of a type to the shipyard

Commercial outlook: Green Methanol (e- and bio-)

Production forecasts
Pricing projections
Regulatory outlook

August 2026

Andrea Lazzaro, Business Development

WIN GD

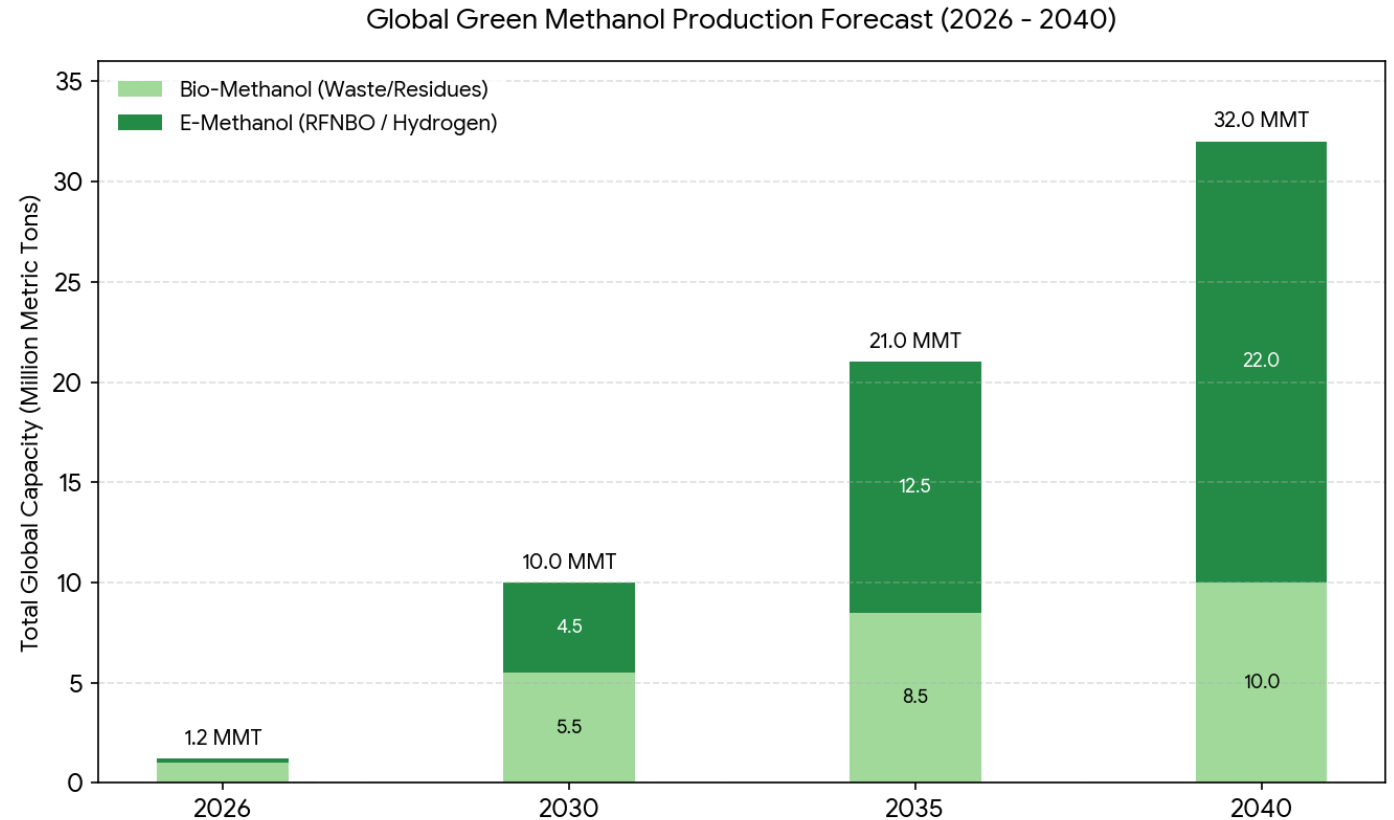
Green methanol expected development

Production ramp-up from current level (near zero) supported by bio-methanol

As more planned projects are expected to be financed and come online in the 2030s, production of e-methanol will eventually surpass bio-methanol.

Both forms of green methanol will face supply limits of biomass. However, the yield of e-methanol per tonne of biomass is 1.1 tons, against 0.4 tonnes for biomethanol. On the basis of a finite global biomass feedstock, economies of scale demanding high process efficiency will favour e-methanol growth.

This scenario is dependent on the adoption of aggressive [IMO 2030/2040 net-zero mandates](#).



Green methanol availability for the marine sector

Strong competition from aviation, automotive and chemical industries expected

Sector / Industry	2026 Share (%)	2030 Share (%)	2040 Share (%)	Key Drivers & Competitive Pressures
Marine Transportation	12.0%	45.0%	45.0%	This sector dominates the 2030 window but faces intense competition by 2040.
Chemicals & Bio-Plastics	80.0%	35.0%	25.0%	Green methanol for formaldehyde, acetic acid, and olefins. They will lose market share as fuel sectors outbid them.
Aviation (Methanol-to-Jet SAF)	0.0%	5.0%	15.0%	Alcohol-to-Jet (ATJ) refining pathways will aggressively target green methanol post-2035 to meet binding global aviation mandates.
Road Transport & Fuel Blending	5.0%	10.0%	10.0%	Used as a direct drop-in gasoline component (M15/M85 blends) or converted to MTBE, primarily in China and northern Europe.
Power Generation & Industrial	3.0%	5.0%	5.0%	Used for specialized low-emission industrial boilers, local backup power grids, and localized thermal plant blending.

Green Methanol pricing projections

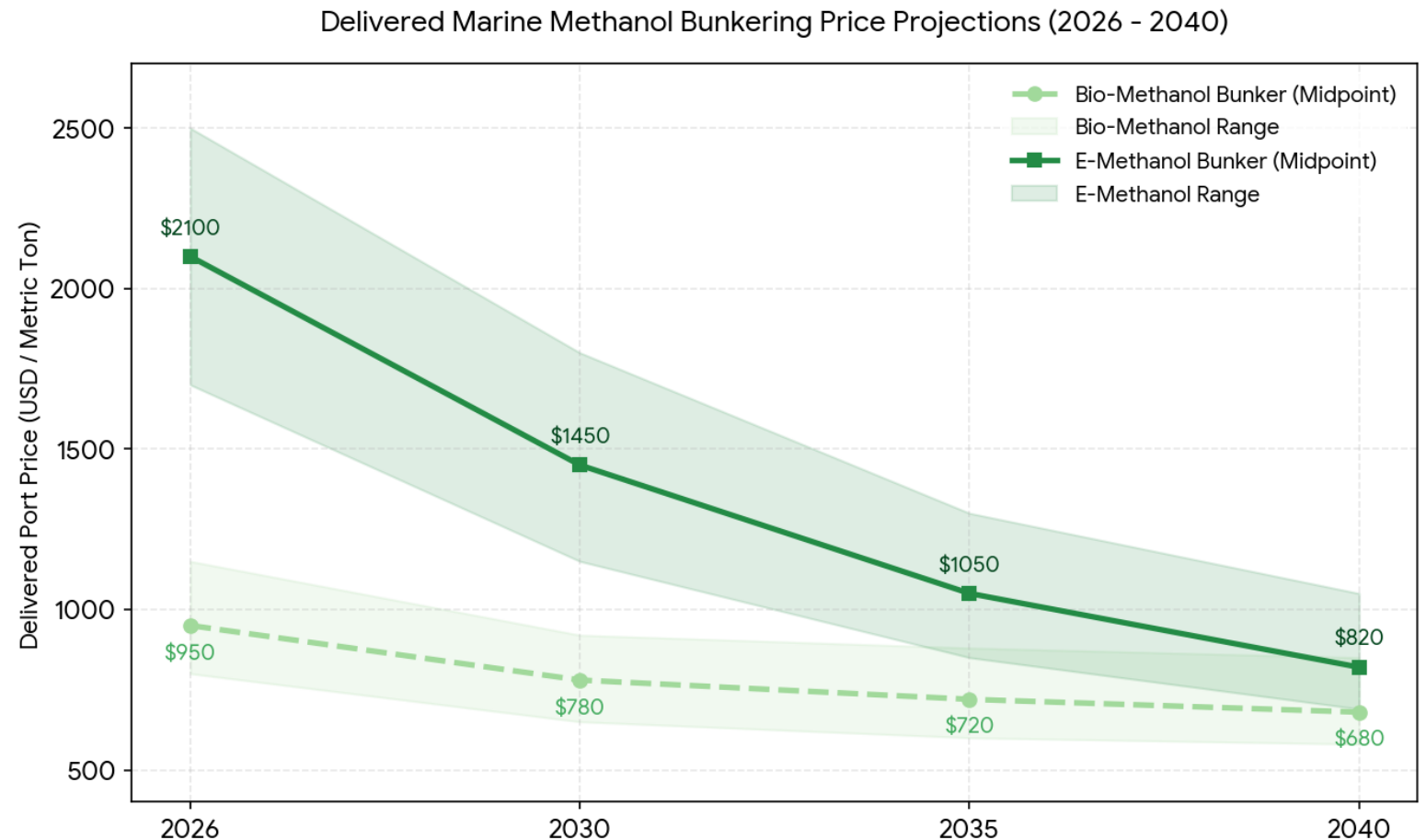
Bio-methanol will always be cheaper, but long-term supply growth is limited.

Switching from "factory-gate" production costs to "delivered-to-ship" port prices shifts the price curve up, well above the base commodity prices.

Bio-methanol holds a sustainable cost advantage because it utilizes mature technology and localized organic waste.

E-methanol carries a massive near-term premium due to the high capital costs of early-stage electrolyzers and energetic penalties associated with sourcing biogenic carbon.

Scaling and standardization will lower e-methanol costs by 2040, but it will remain more expensive than bio-methanol due to the energy cost.



Commercial Outlook

Ethanol as marine fuel

Production forecasts
Regulatory outlook

August 2026

Andrea Lazzaro, Business Development

WIN GD

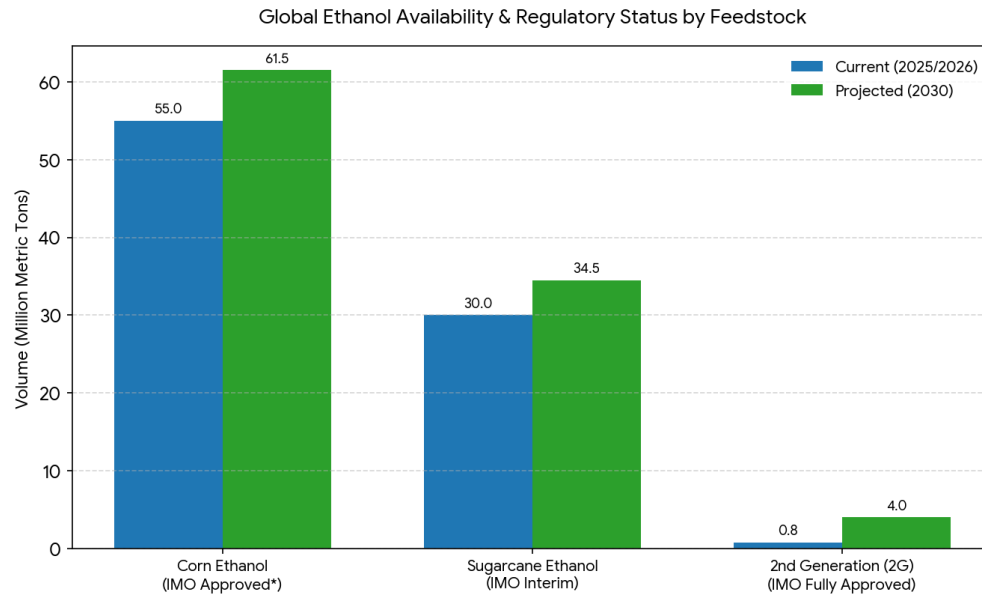
Ethanol compliance with FuelEU and IMO, 2026-2030

Contradictory regulations ahead of IMO decisions on NZF

Feedstock Type	Current Volume	Projected 2030	FuelEU Maritime Status	IMO Compliance Status
Corn Ethanol	55.0 MMT	61.5 MMT	Not Credited / Capped: Excluded from credit calculations due to EU food-vs-fuel restrictions.	Conditionally Approved: The IMO officially certified Brazilian second-crop corn ethanol with a default value of 20.8 gCO ₂ eq/MJ, making it highly effective for lowering a ship's CII rating.
Sugarcane Ethanol	30.0 MMT	34.5 MMT	Highly Restricted: Subject to stringent Indirect Land Use Change (ILUC) limits.	Pending Certification: Broadly permitted under IMO's interim biofuel rules (if certified sustainable via ICAO/CORSIA frameworks). Brazil is actively pushing for an explicit standalone IMO default value.
2nd Generation (2G)	0.8 MMT	4.0 MMT	Fully Compliant: Cellulosic and waste-derived ethanol face no crop caps and maximize compliance credits.	Fully Approved: Waste-residue cellulosic pathways receive the highest structural emissions savings under the IMO LCA Guidelines .

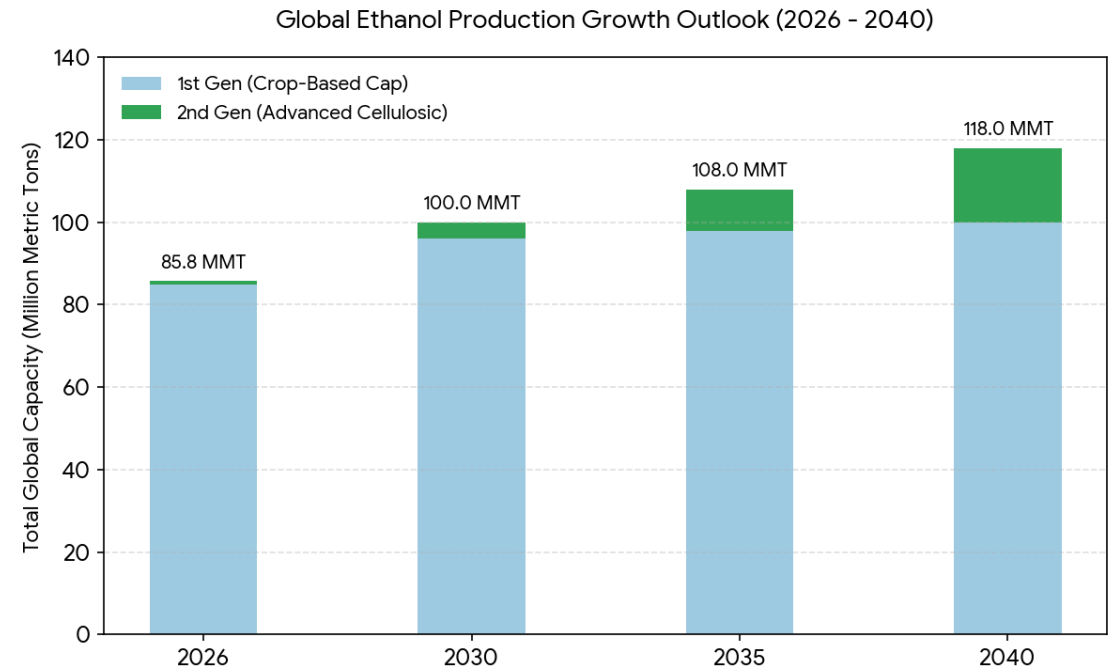
Global ethanol availability forecasts

1st generation ethanol, if produced sustainably, could be the major feedstock



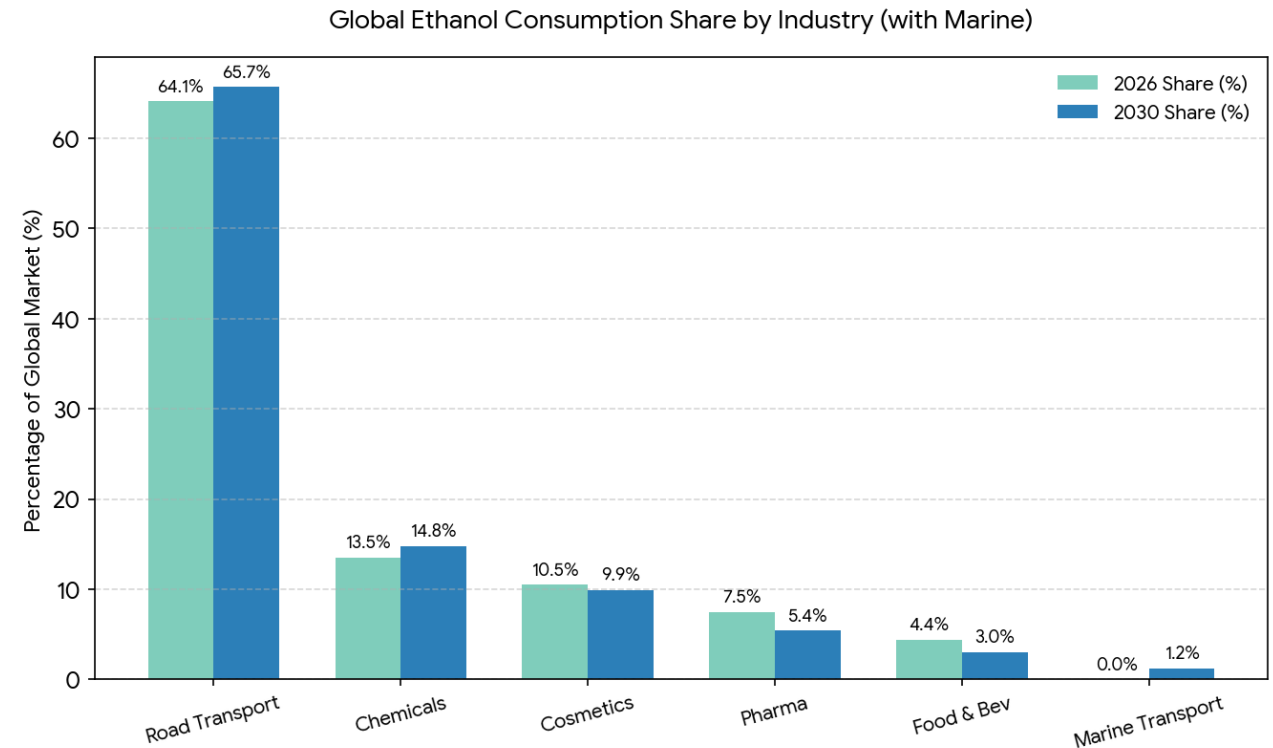
The total global ethanol market across all feedstocks is approximately **85.8 Million Metric Tons (MMT)** in **2026** and is projected to expand to **100.0 MMT** by **2030**.

Longer term projections towards 2040 show growth of 2nd generation ethanol, bringing the total production worldwide to **118MMT**. Further untapped growth regions include Africa and Asia (including China).



Regulatory impact and competitive challenges

- Current demand by the marine sector is at its very early stage.
- If global shipping secures regulatory mandates (overcoming EU resistance and harmonizing with IMO directives) to include widely available crop-based ethanol, the maritime sector could unlock **over 20 MMT of annual ethanol demand** beyond 2030.
- The main competitive challenges come from aviation **Ethanol-to-Jet (ETJ)** refining mandates legally locked in for 2030, and from the **chemical industry** (to make low-GHG plastics by replacing the use of ethane for ethylene production) beyond 2035.



Ethanol pricing forecasts

Price uncertainty will increase over time, due to external competitive factors

1. Sustainable Aviation Fuel (SAF) competition

By the 2030s, **Ethanol-to-Jet (ETJ)** technology is projected to mature commercially. Ethanol will become a premium feedstock for jet fuel, driving prices up dramatically.

2. Chemical Industry competition

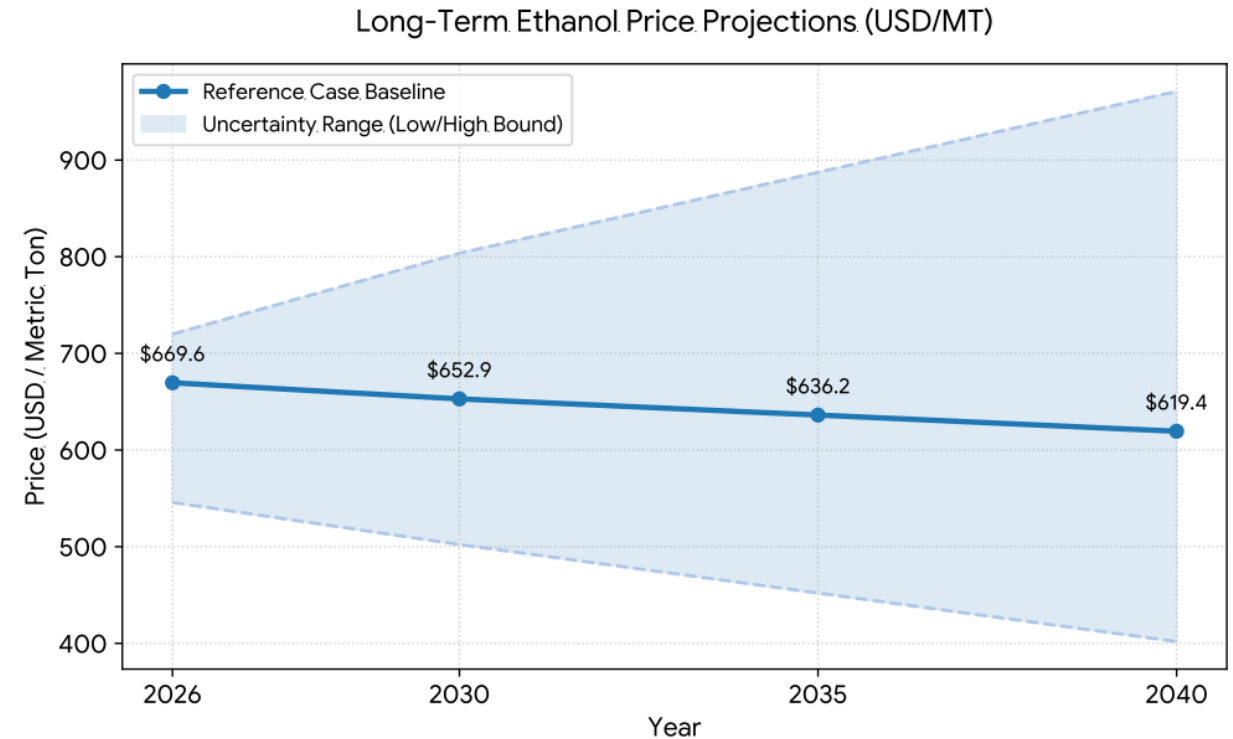
The chemical industry is under pressure to replace petroleum-based ethylene with bio-based alternatives.

Ethanol is the primary candidate for bio-ethylene. Chemical industries will bid up ethanol price to meet environmental mandates.

3. Agricultural and Resource Constraints

Climate Volatility: More frequent extreme weather events threaten crop yields, drastically raising feedstock costs.

Land-Use Competition: Stricter global regulations will cap supply even as alternative demand spikes.



Thank you

Propelling shipping
towards a
greener future

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