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Methanol: A Future Proof Marine Fuel

Gregory Dolan, CEO

Alternative Energy Sources in the Shipping Industry – MSc in Marine Science and Technology Management
30 June 2021

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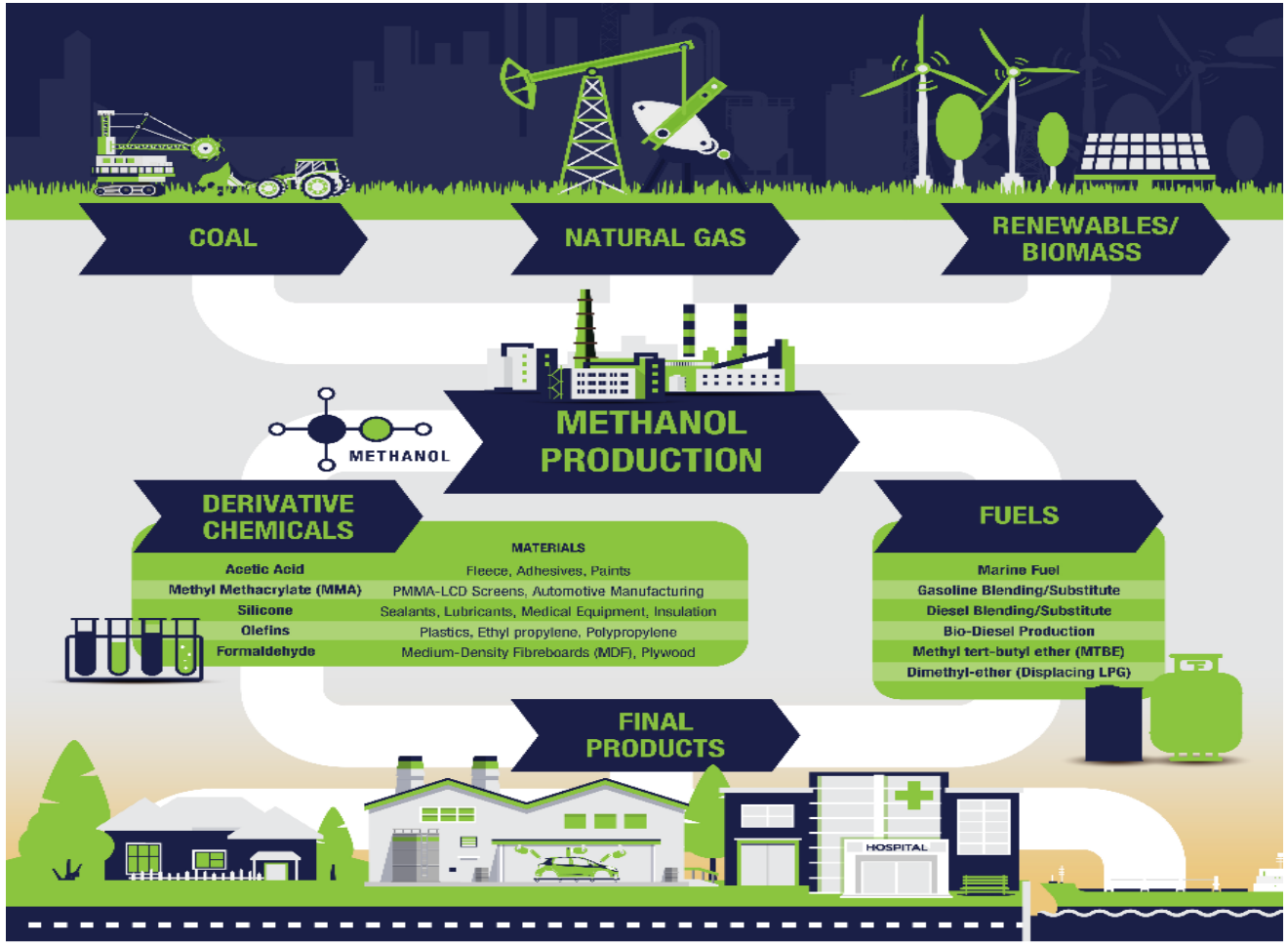
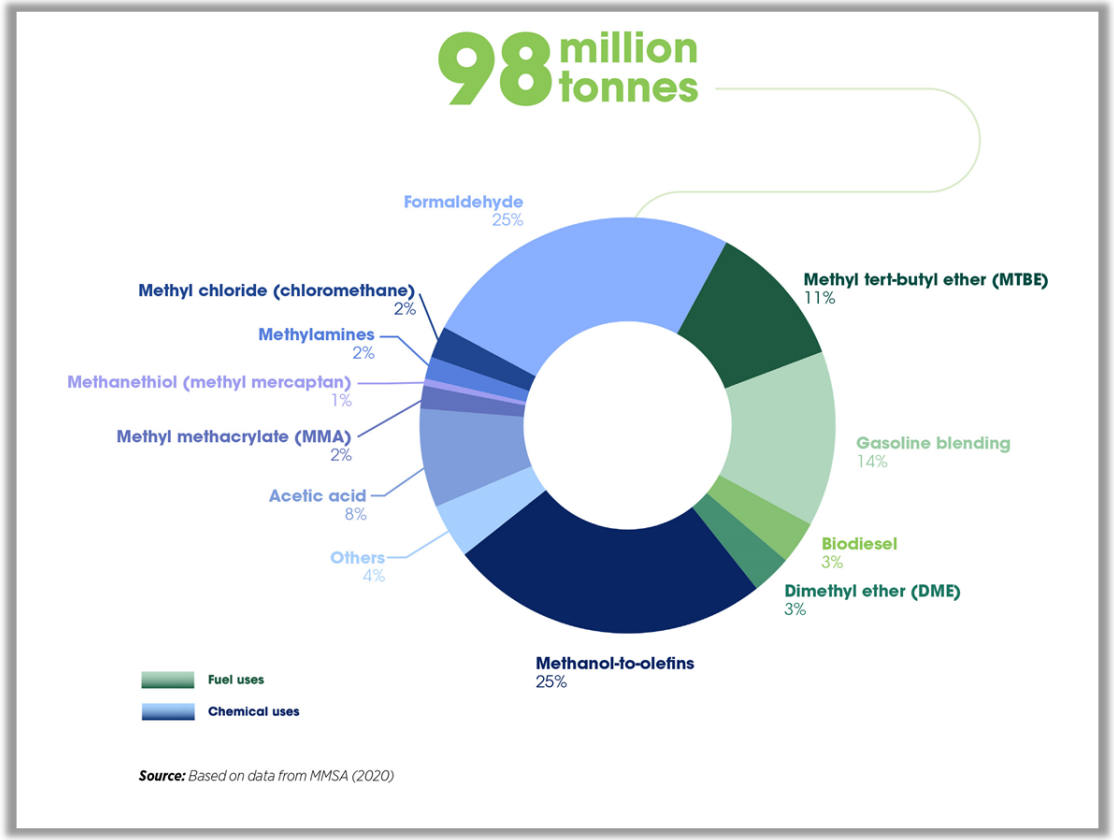
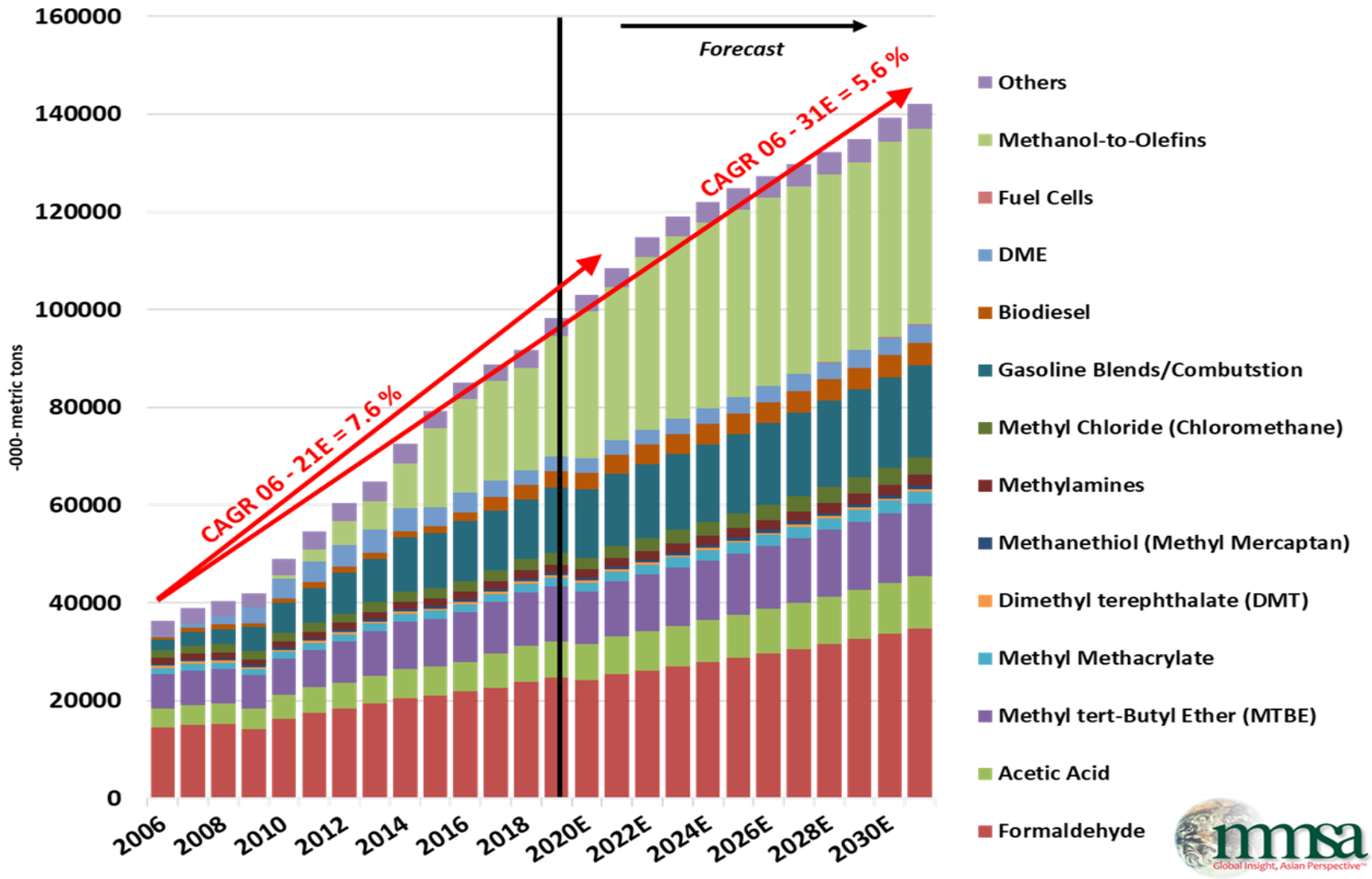
Essential Methanol



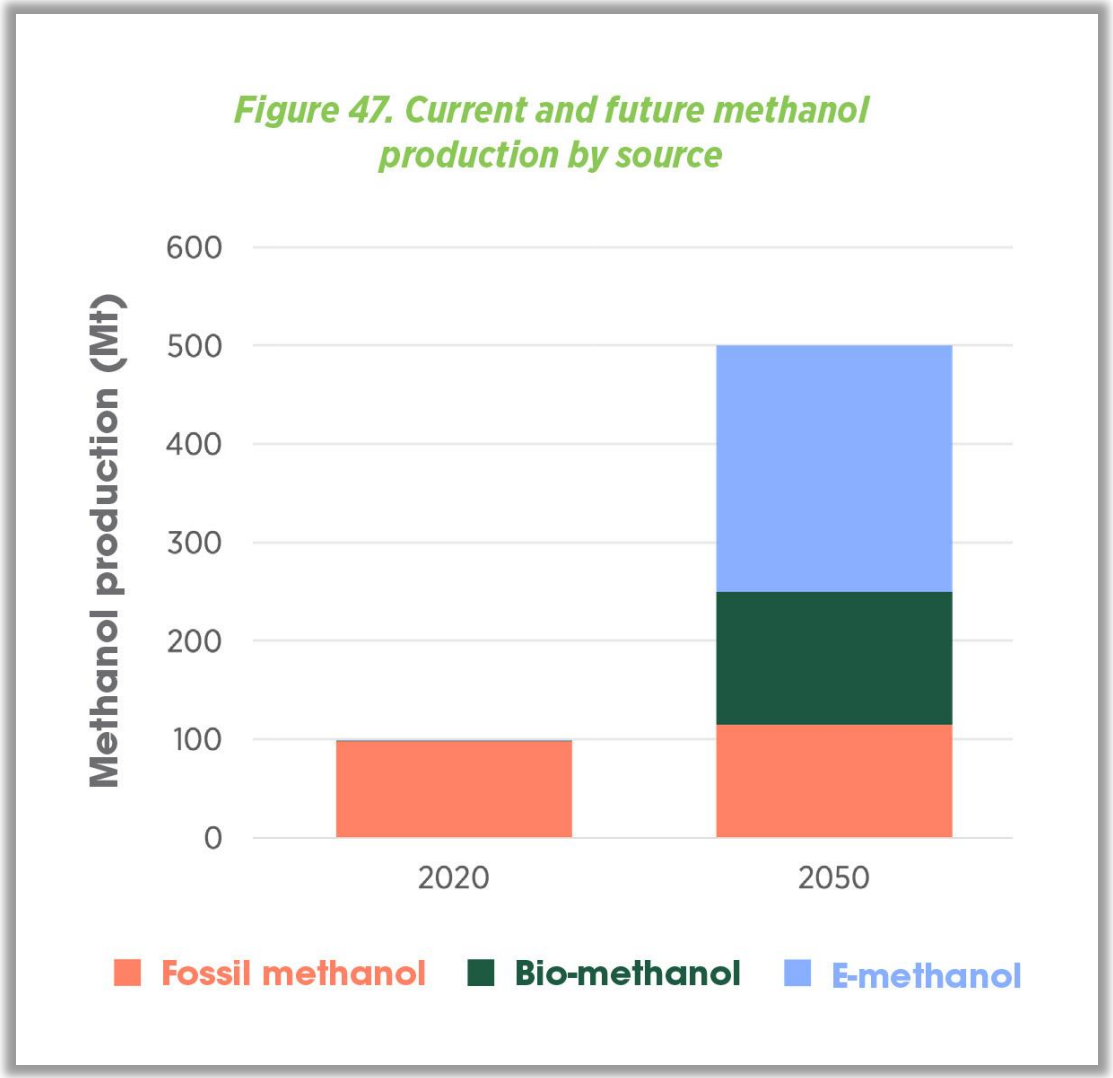


Driven by China MTO



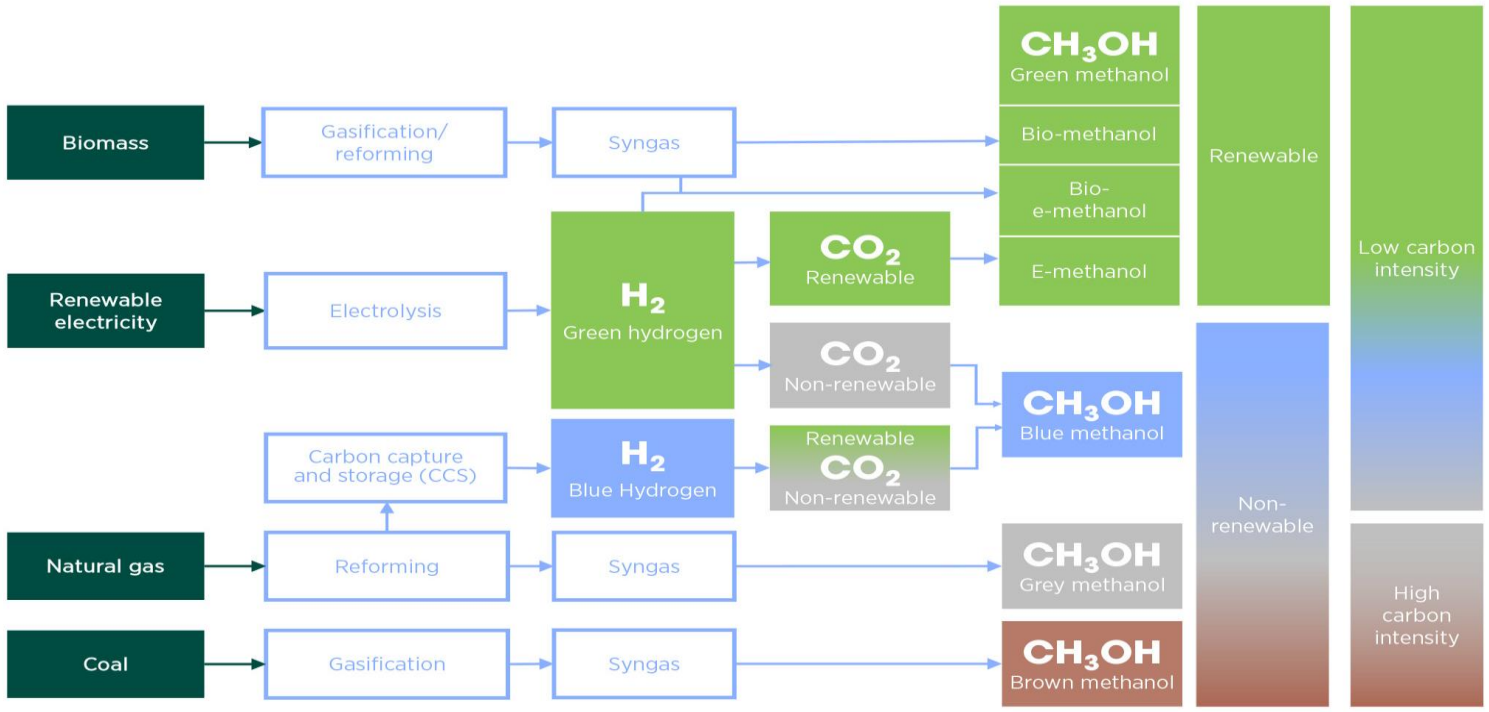
2050: 5-Fold Demand Increase

https://www.irena.org/publications/2021/Jan/Innovation-Outlook-Renewable-Methanol



Brown, Grey, Blue and Green

Figure 2. Principal methanol production routes

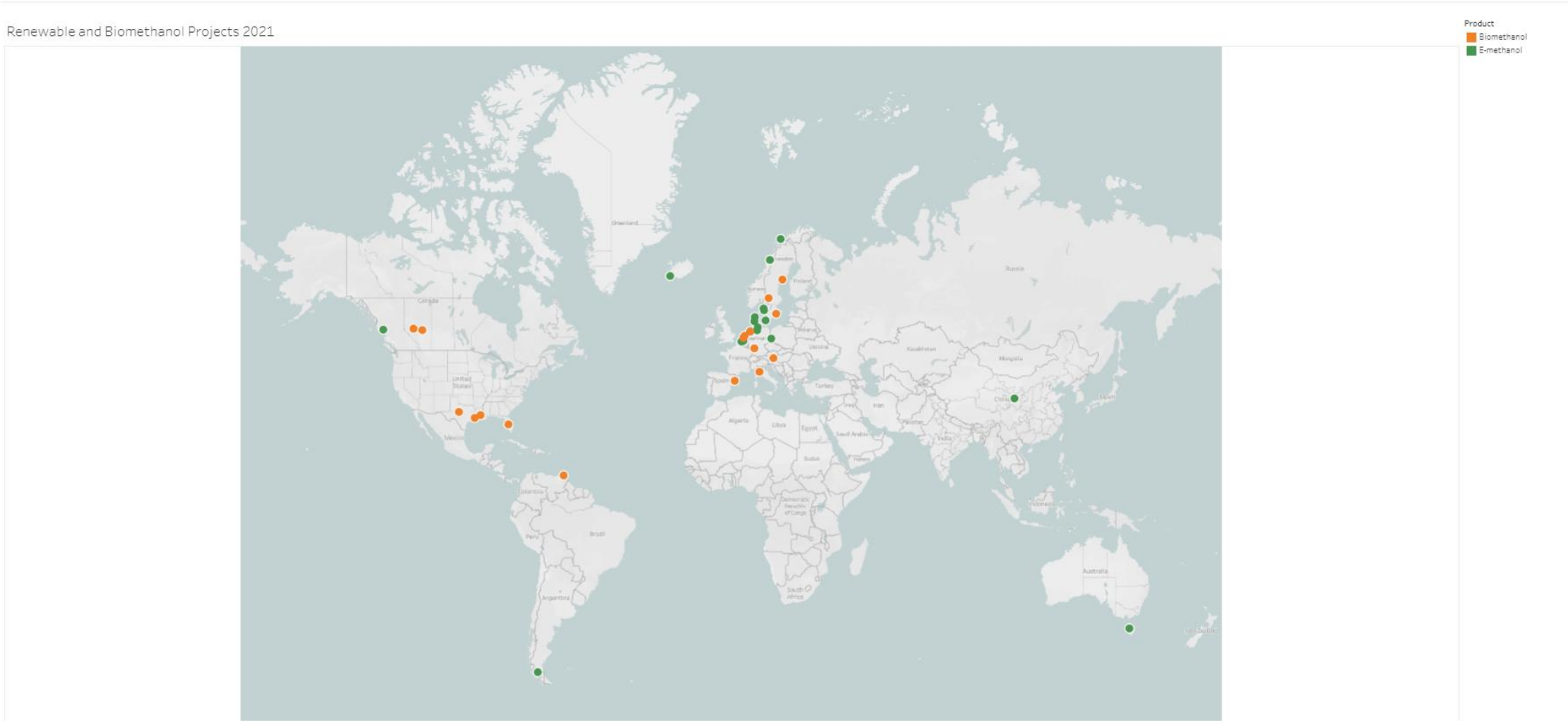


Renewable CO_2: *from bio-origin and through direct air capture (DAC)*

Non-renewable CO_2: *from fossil origin, industry*

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

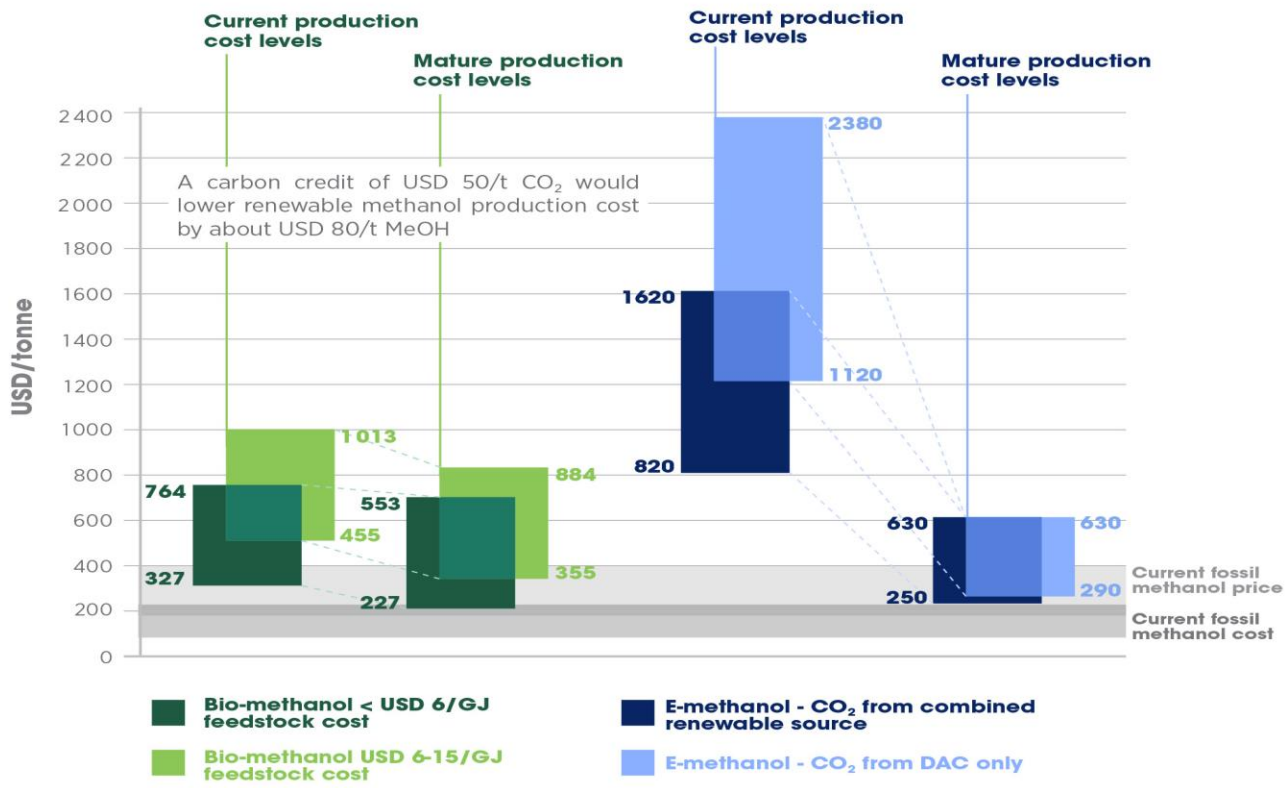
E-Methanol and Bio-Methanol Projects



https://www.methanol.org/renewable/

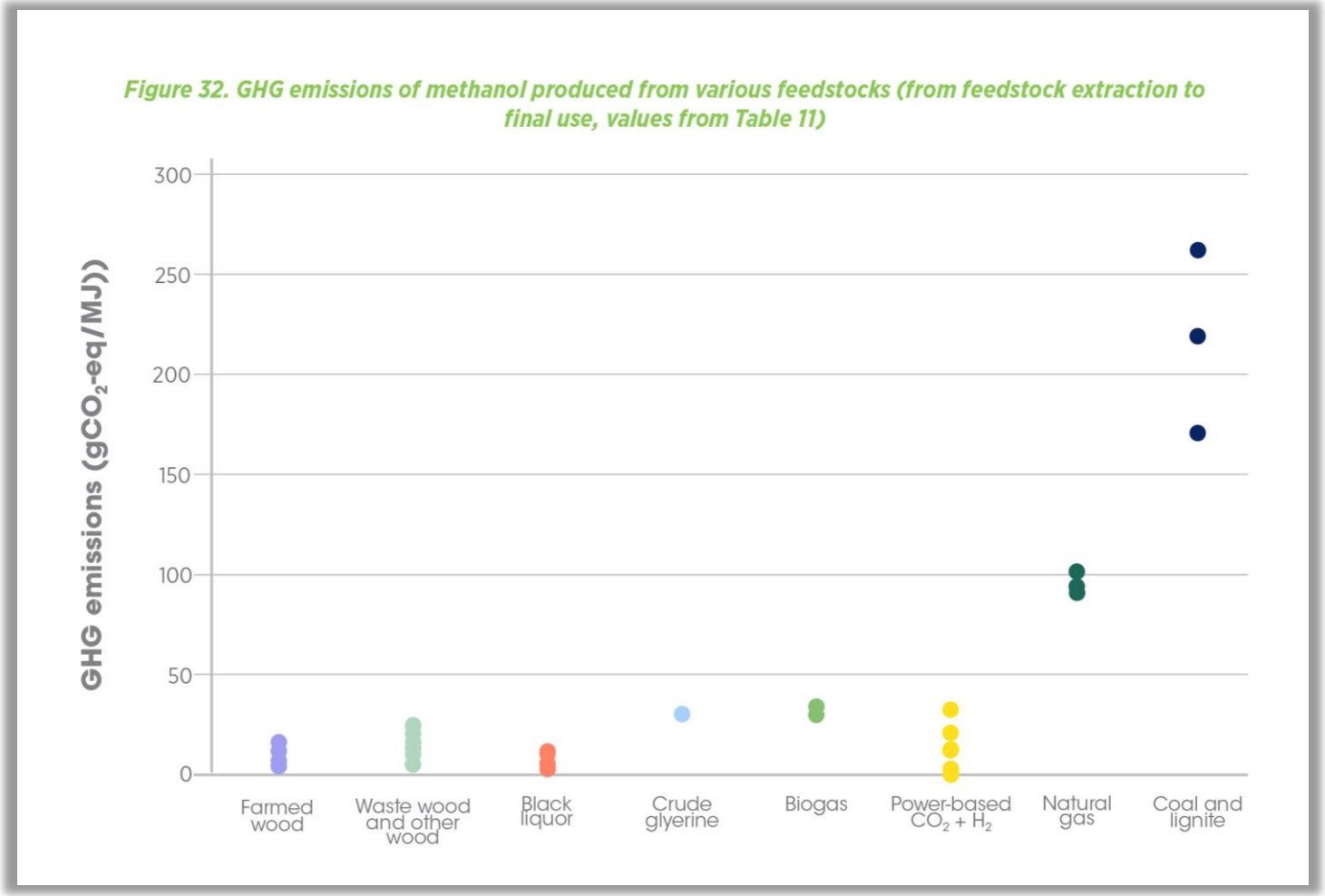
Cost of Production

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



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

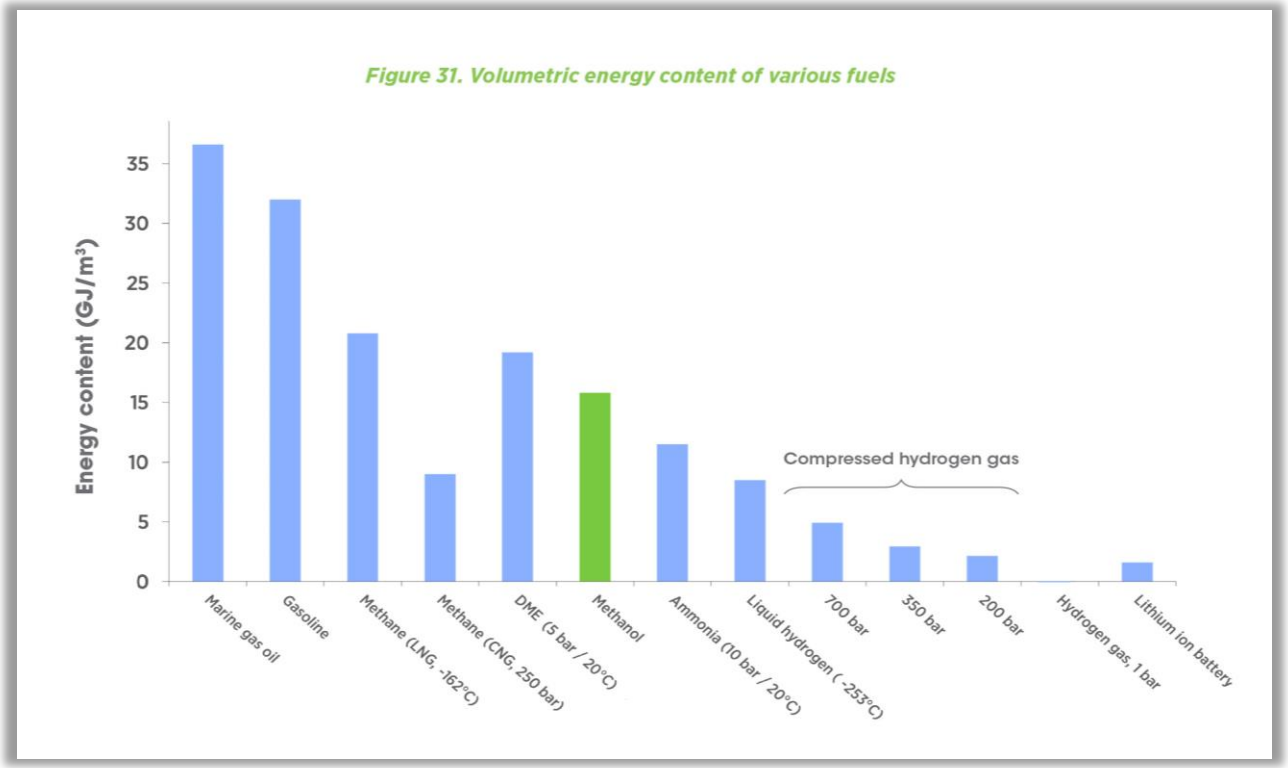
Methanol GHG Emissions

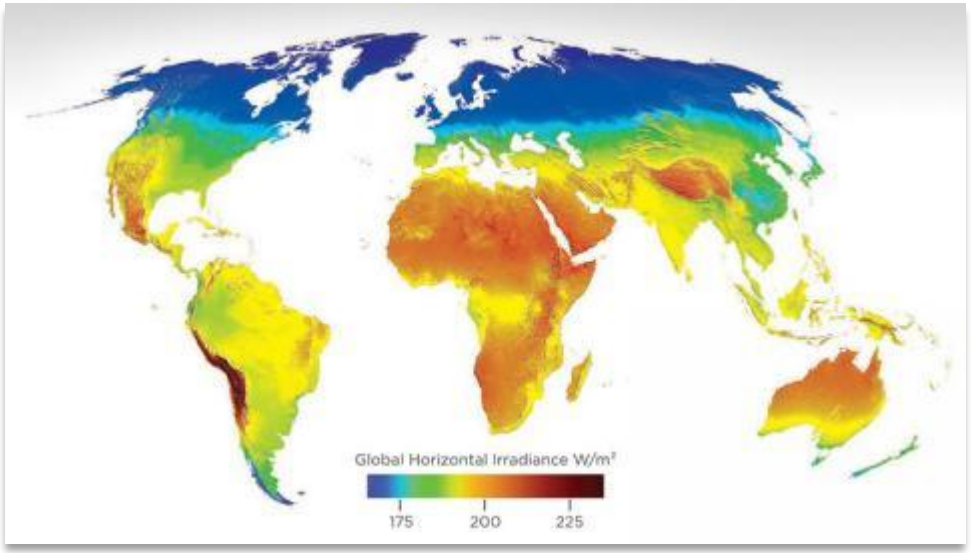


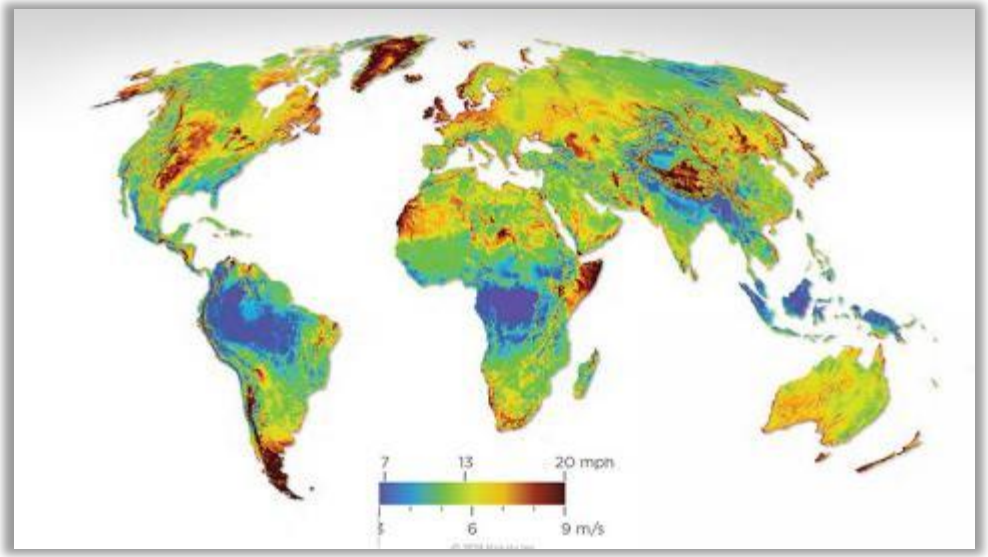
Methanol Emissions Profile

Source: Stena Lines -- Emission reductions when compared to alternative fuels currently available (fuel oil)

Fuel Comparison

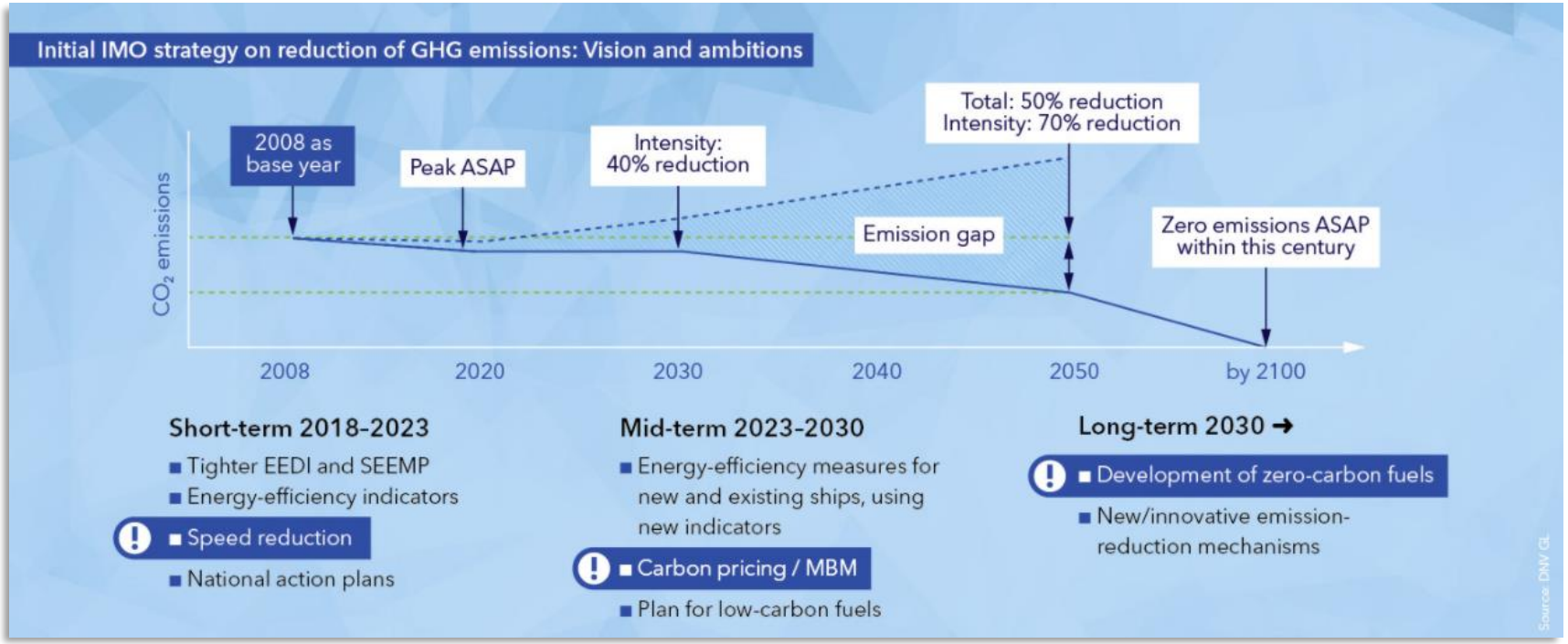




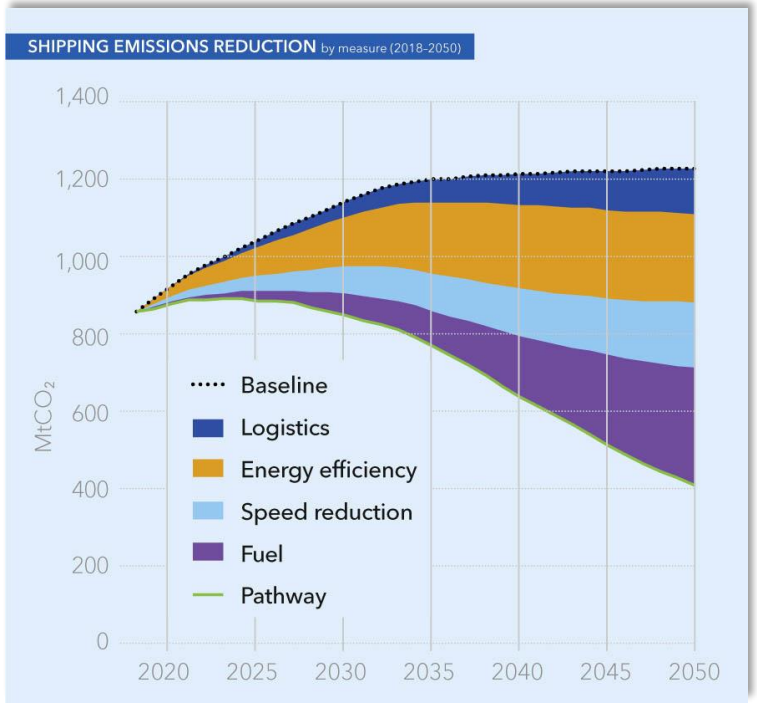


Fuel Use Developing Globally

IMO 2050 GHG “levels of ambition”



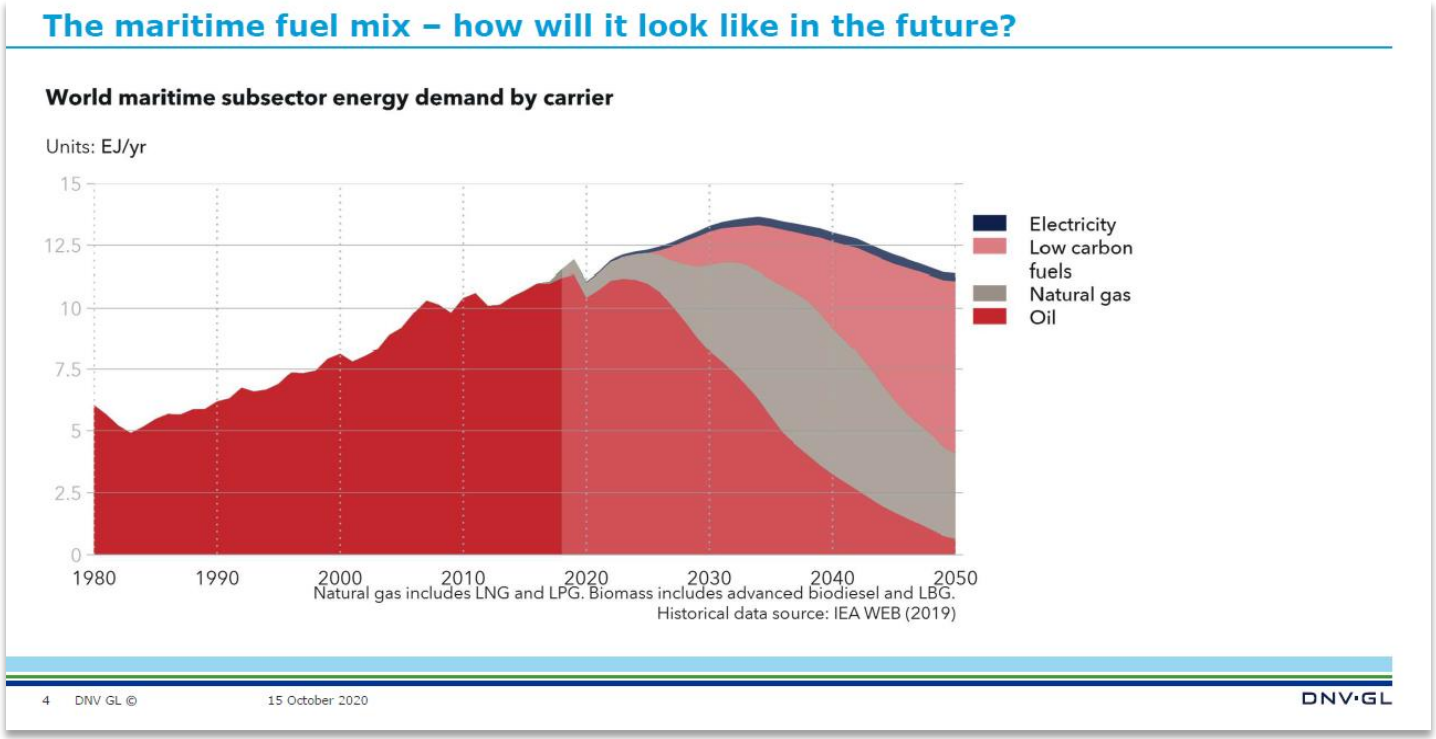
https://www.dnvgl.com/expert-story/maritime-impact/How-newbuilds-can-comply-with-IMOs-2030-CO2-reduction-targets.html



https://www.dnvgl.com/expert-story/maritime-impact/the-future-proof-ship.html

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

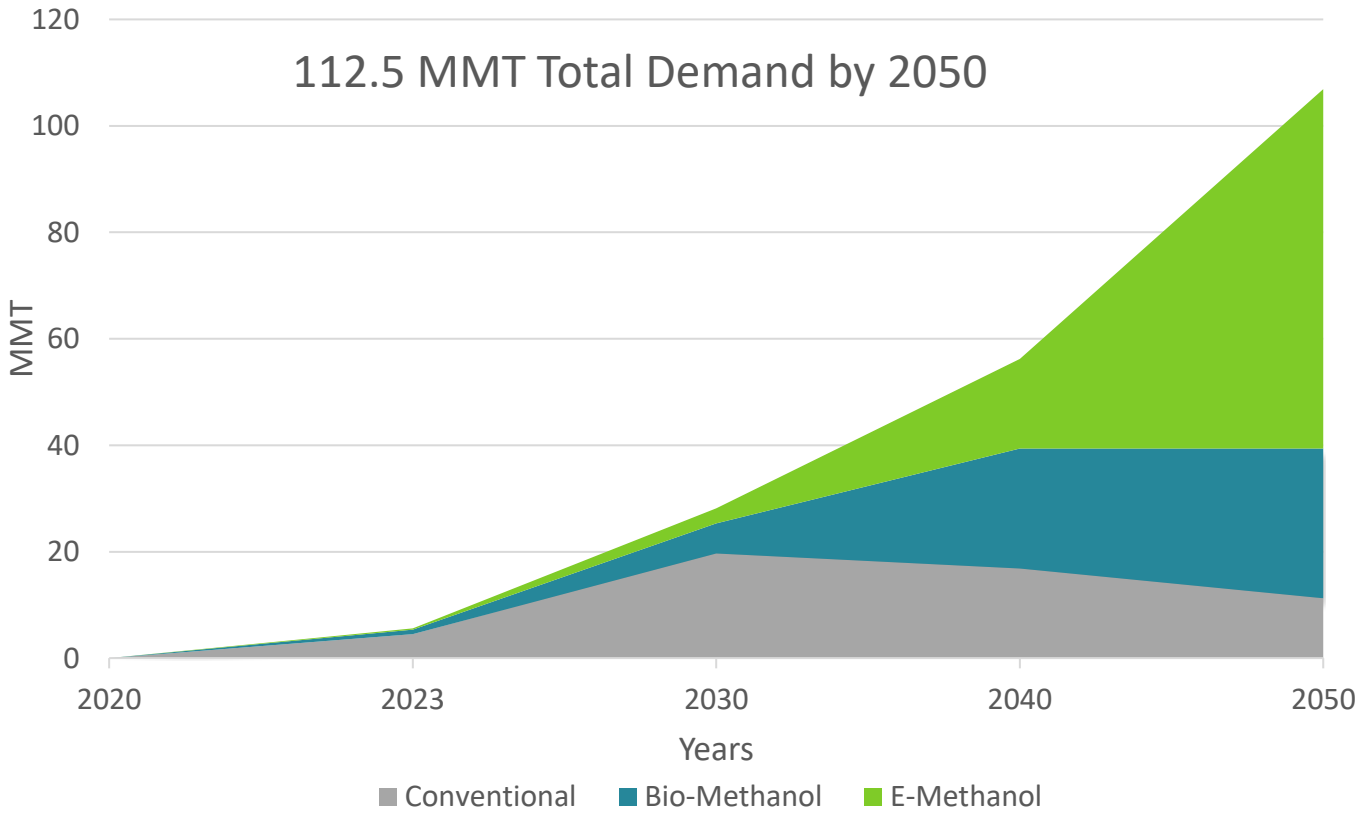
Maritime fuel mix sea change



https://www.dnvgl.com/expert-story/maritime-impact/Prepare-for-a-decarbonization-pathway.html

- DNV-GL 2050 Maritime Forecast assumes that a mixture of improved utilization and energy efficiencies, combined with a massive fuel decarbonization, will see IMO 2050 goal being met
- Shipping's fuel mix in 2050 will have switched from being almost entirely oil dominated today, to a mix dominated by **low- and/or zero-carbon fuels (60%)** and natural gas (30%, mostly LNG)
- Fossil LNG gains a substantial share following the IMO ambitions. However, as regulations tighten in ***2030 or 2040***, depending on the decarbonization pathway, we see bio-LNG, e-LNG, bio-MGO and e-MGO used as drop-in fuel for existing ships, ***while bio-methanol, blue ammonia or e-ammonia are used for newbuilds and some retrofits***
- In the Decarbonization ***by 2040*** scenarios, instead of a transition via LNG, ***the fleet shifts directly to carbon-neutral methanol or ammonia***, with bio-MGO and e-MGO as drop-in fuels for existing ships

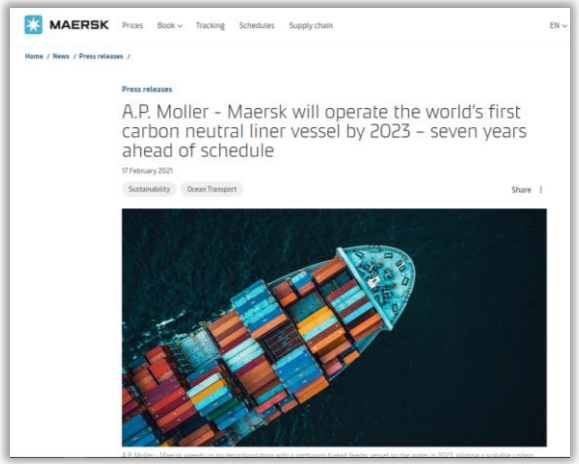
What is potential methanol prize?



Assumption: 25% 2050 demand = 2.25 EJ (per DNV) = 112.5 MMT methanol, see similar calculation for ammonia, https://www.ammoniaenergy.org/articles/maritime-fuel-mix-could-be-25-ammonia-by-2050/

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

Maersk: Methanol Game Changer



https://www.maersk.com/news/articles/2021/02/17/maersk-first-carbon-neutral-liner-vessel-by-2023

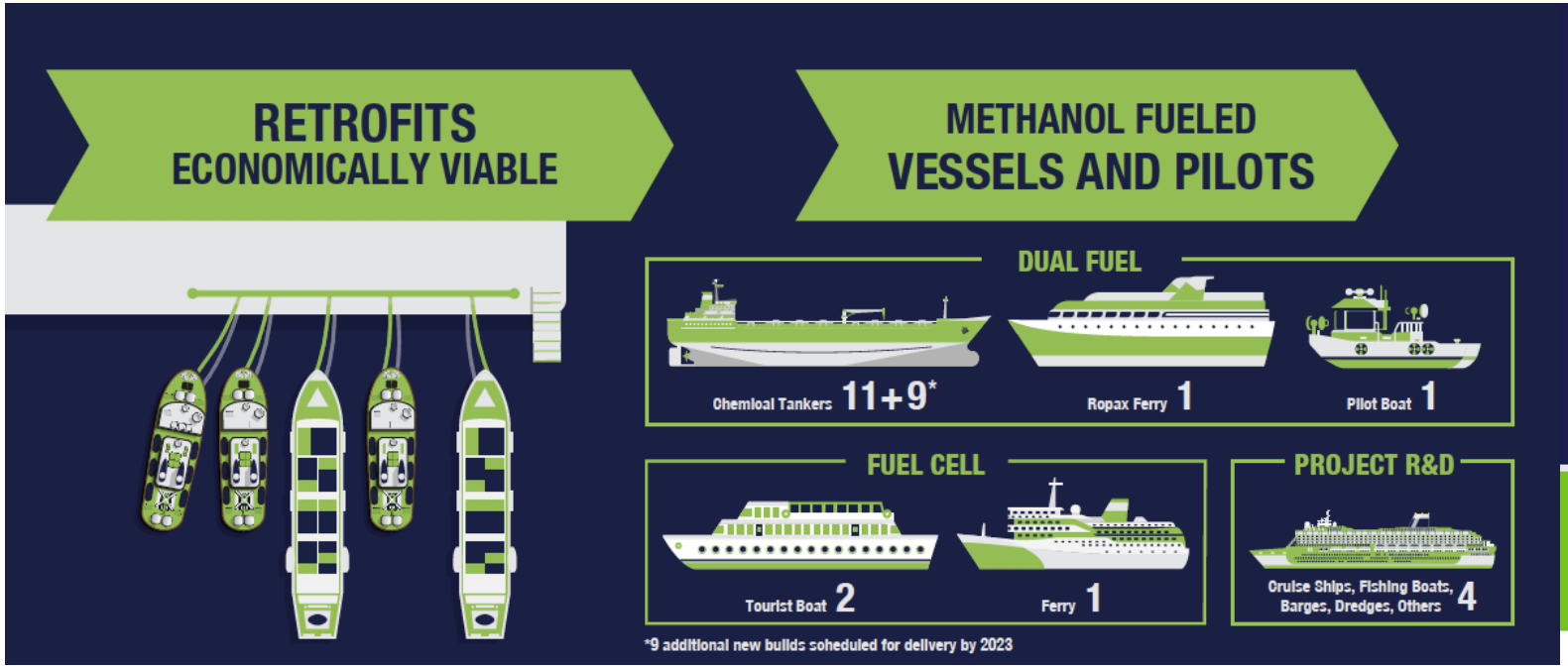
"The reason that we have gone for methanol on the first one is that it is the most mature from the technology perspective; we can get an engine that can burn it." Morten Bo Christiansen, head of decarbonization at Maersk

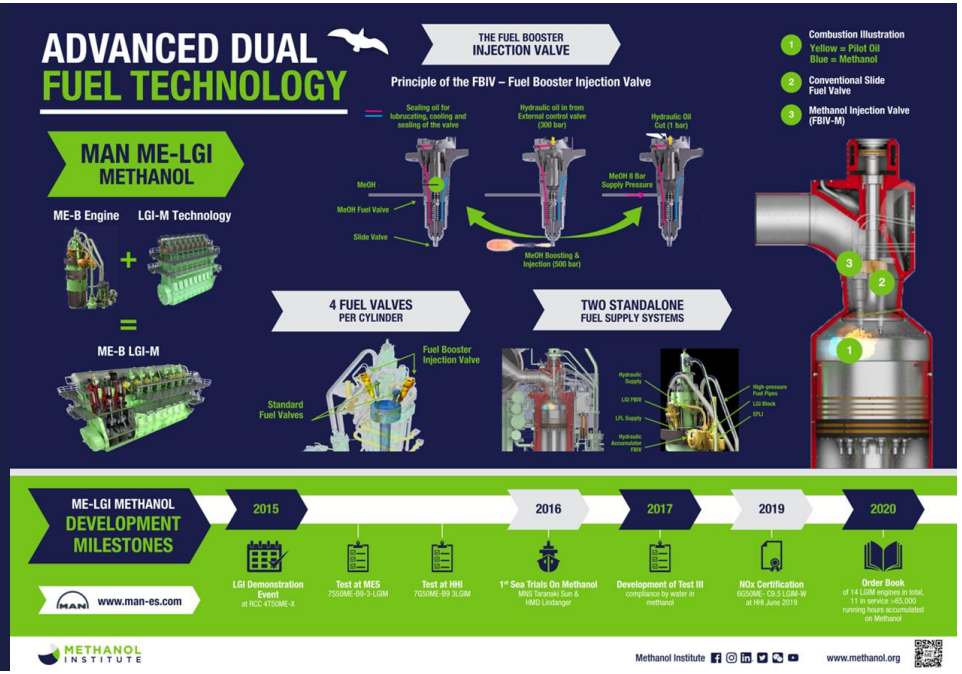
"That means that if we end up finding exactly the right solution then there will be a big retrofit opportunity for us." Maersk CEO Soren Skou speaking during Maersk's on 10 February earnings call

- 21 Feb 2021: Maersk announces that the world's first carbon neutral container vessel by 2023 will operate on dual-fuel methanol
- All future new builds will be dual-fuel
- Maersk has now order three methanol duel-fueled vessels from Korean shipyard.

"It will be a significant challenge to source an adequate supply of carbon neutral methanol within our timeline to pioneer this technology. Our success relies on customers embracing this groundbreaking product and strengthened collaboration with fuel manufacturers, technology partners and developers to ramp up production fast enough. We believe our aspiration to put the world's first carbon neutral liner vessel in operation by 2023 is the best way to kick start the rapid scaling of carbon neutral fuels we will need," says Henriette Hallberg Thygesen, CEO of Fleet & Strategic Brands, A.P. Moller - Maersk

100,000 Hours of Operations

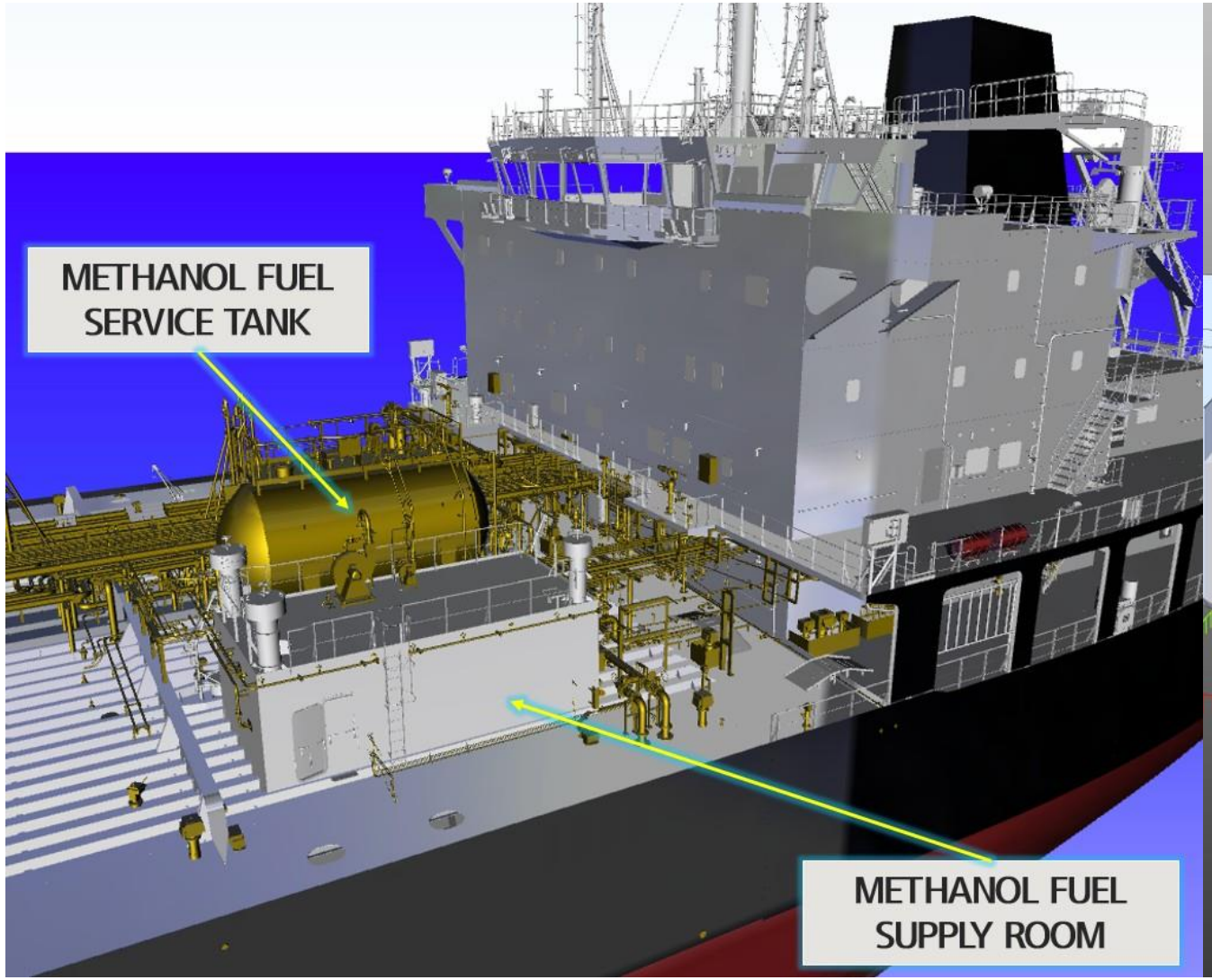


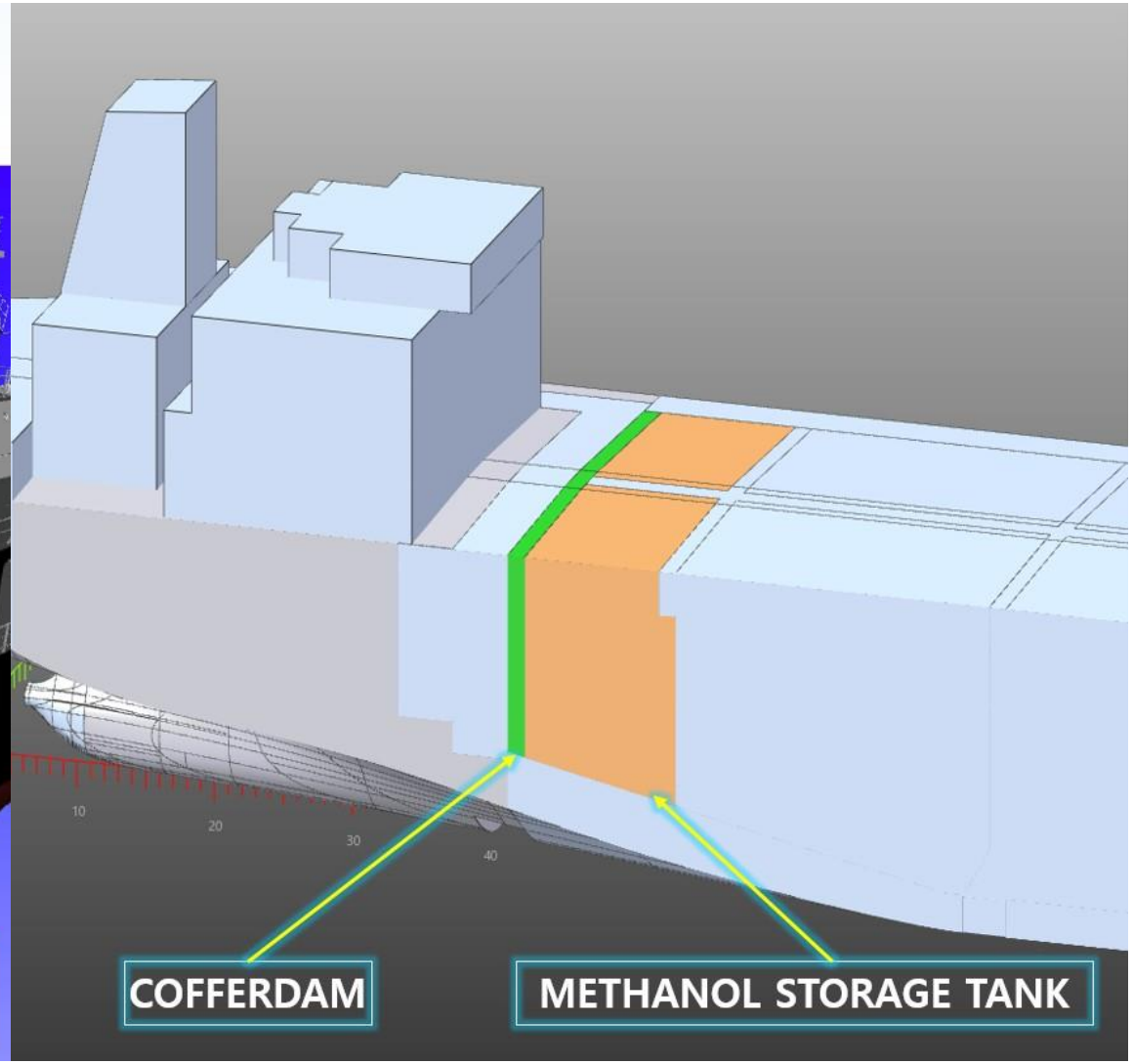


More on the Way

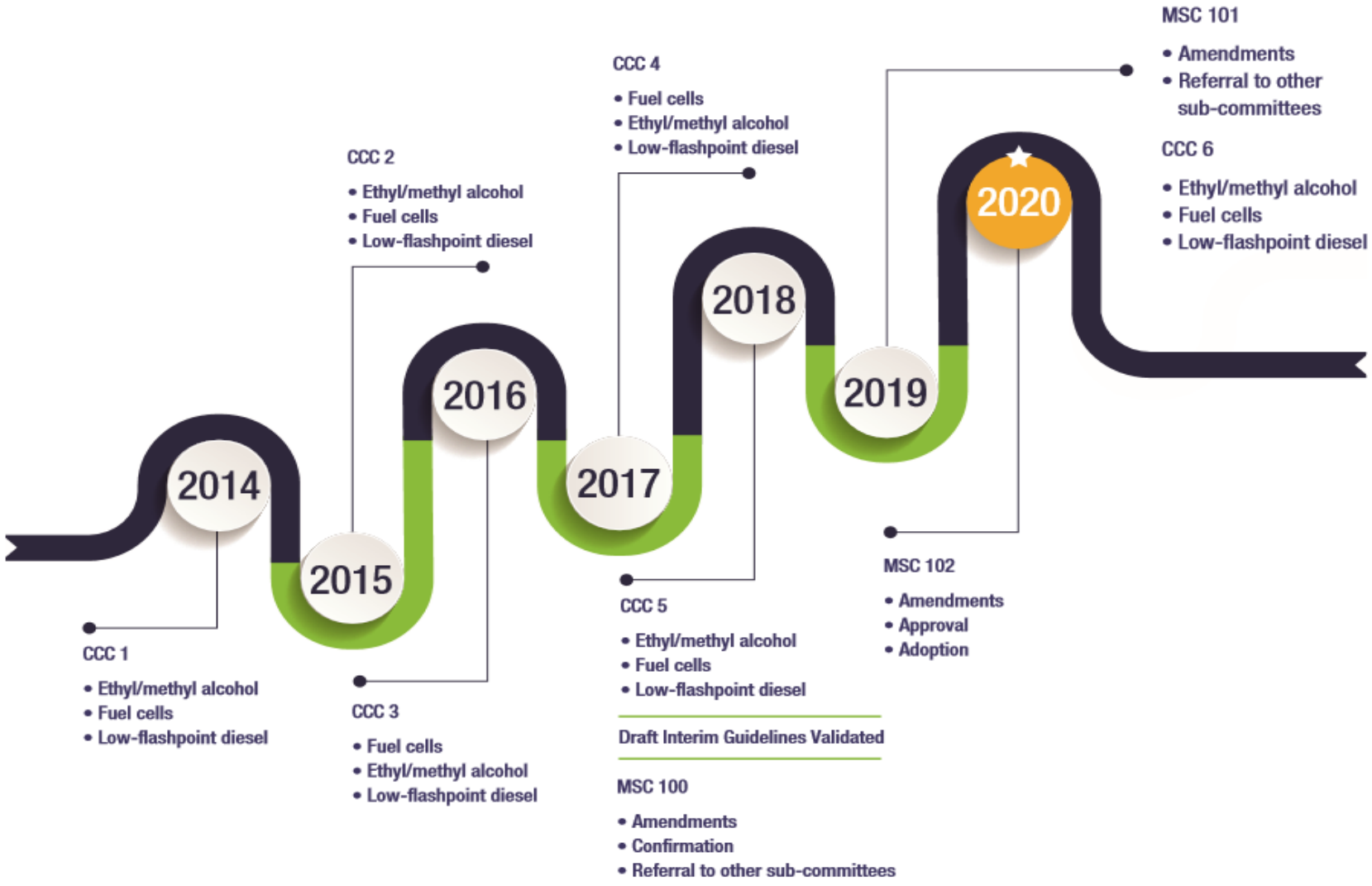
- *Denmark:* Maersk *to operate w*orld's first carbon neutral liner by 2023 methanol dual-fuel
- *Netherlands:* OCI NV, MAN, Eastern Pacific Shipping first methanol retrofit by 2023, newbuilds and retrofits
- *Sweden/Switzerland*: Proman Stena Bulk – joint venture of shipowner Stena Bulk and Proman Shipping a subsidiary of methanol producer Proman – to build four 50,000 dwt tankers with methanol dual-fuel engines first deliveries 2022
- *United States*: NWIW partners with Hafnia and MOL for dual-fuel vessels
- *Netherlands:* Damen Shipyards delivering two methanol tugs to Port of Antwerp in 2021
- *Netherlands*: Damen Shipyards has developed new concept Offshore Support Vessel (OSV) to operate on methanol
- *Japan*: Sumitomo Heavy wins Approval in Principle from ClassNKK for methanol dual-fuel tanker
- *Germany*: Shipowner Liberty One has ordered new multipurpose (MPP) ship powered by methanol
- *Germany*: Shipowner SAL Heavy Lift to install FUELSAVE hydrogen/methanol injection system in 6 vessels
- *Germany*: Abeking & Rasmussen shipyard designing "green cruise" concept vessel using methanol fuel cells for hotel load and methanol propulsion engines
- *Germany*: AIDAnova will employ methanol fuel cells for propulsion as early as 2021 under Pa-X-ell2 project
- *Germany*: Shipyard Fassmer has order from Alfred Wegener Institute to build methanol-powered research vessel UTHORN

Methanol dual fuel standardized design





IMO IGF Code Methanol Approval



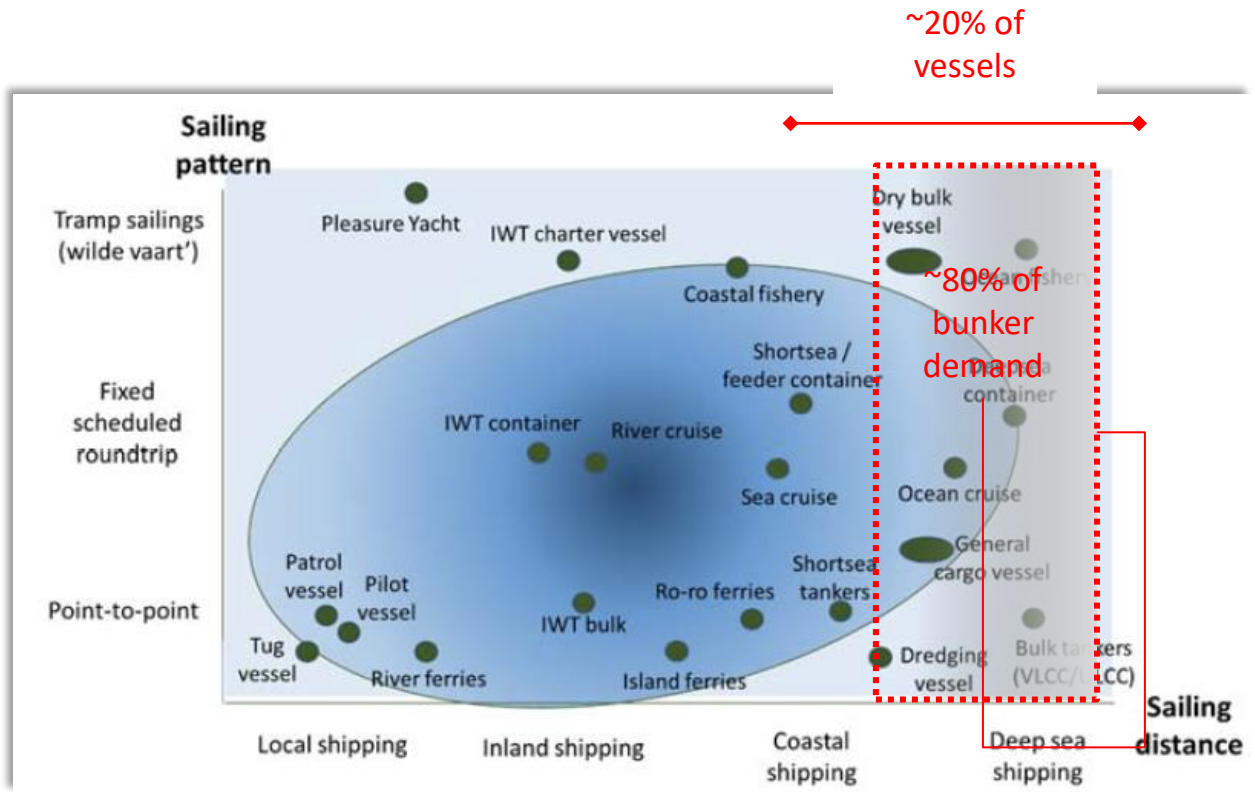
Green Maritime Methanol

- MI part of an industry consortium organized by TNO to study the use of (green) methanol in short sea shipping, a spin-off from the Horizon 2020 LeanShips project.
- TNO is an internationally renowned research institute with a great reputation for objective analysis.
- The GMM 1.0 study set the stage for a pilot with actual ships on the water with project partners (Horizon 2020 or other) under GMM 2.0.
- Focus is on renewable methanol but the technology, safety guidelines and policy can be used for conventional methanol too.

https://greenmaritimemethanol.nl/

TNO: Potential vessel segments

- For Green Maritime Methanol program, TNO conducted assessment of market potential for Dutch/EU market for methanol as a marine fuel
- Heatmap of “methanol-applicability of shipping segments”
- Most shortsea and inland shipping markets appear feasible in terms of operational profiles, fuel consumption and sailing patterns
- But important to recognize that the ocean-going vessels make of 20% of vessels and fully 80% of bunker demand

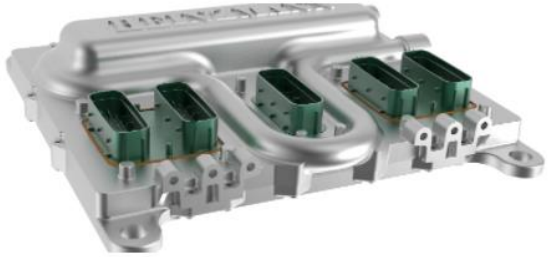


Source: TNO Report for GMM, Sept 2020

GMM CAT Engine Conversion

- Feb 2020: As part of the Netherlands Green Maritime Methanol test programme, PON Power converted a CAT 3408 natural gas spark ignition engine to run on 100% methanol
- Proof of concept built in under 6 months, the first objective was to get the engine to run, which it did with relative ease
- The engine runs at 1,500 RPM, with power output of 517 kW at 1:12 compression ratio, but operation limited to 420 kW due to insufficient fuel pump capacity
- Used automotive injectors for demonstration purposes, customized heads with in-cylinder sensors (provided by CAT HQ)

Fastwater.eu



Methanol engine retrofit solutions (WP1)

Work Package 1 mission is to provide turnkey methanol conversion kits as a retrofit solution for high speed and medium speed diesel engines (200kW-4000kW). more

Harbour tug demo (WP2)

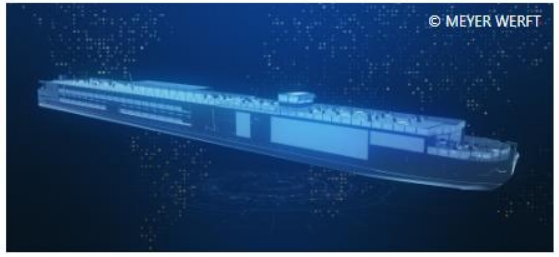
Work Package 2 mission is the complete conversion of a harbour tug (owned by PoA) for methanol/MGO dual-fuel operation incl. set up of supply chain and training of crew. more

Pilot boat demo (WP3)

Work Package 3 mission is to demonstrate methanol as a fuel for use in a smaller marine application for a longer period during true operational conditions. more

Coast guard vessel demo (WP4)

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



Methanol river cruise ship conversion concept (WP5)

Work Package 5 mission is to develop the conversion concept for a River Cruise Ship for a fuel change from diesel to a methanol-driven propulsion system. more

Next generation methanol engines (WP6)

Work Package 6 mission is to develop the next generation of methanol engines, that fully exploit methanol's beneficial properties as an engine fuel, for increased efficiency and even lower emissions. more

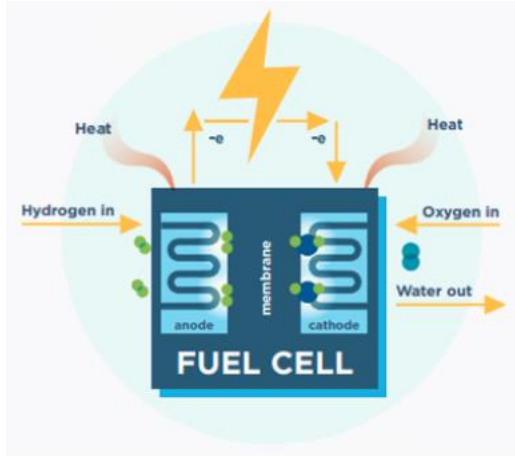
Lund University
Ghent University
Anglo Belgian Corporation — We power your future
methanex — the power of agility
Heinzmann
BALance Technology Consulting
SSPA
Super Toys — Boats · Engines · PWC · ATV
ScandiNAOS AB
Meyer Werft — Papenburg 1795
Lloyd's Register
Swedish Maritime Administration
Port of Antwerp

Includes National Technical University of Athens – WP1 High Speed Engines

Methanol as Hydrogen Carrier

E1 L-series reformer: 65kg/day

Purified H_2



H2 fuel cells produce clean electric power which can be used in a wide array of applications

Clean power

- Nascent but growing interest – shipping companies are taking note
- Recent webinar detailing *The Methanol Pathway to Hydrogen* drew 200
- Fuel cells or hybrid systems can be a more efficient pathway to produce power
- Key driver is cost:

	EU	N America	APAC	China
Cost of methanol $/MT	$308.94	$332.25	$275.00	$275.85
Cost for producing 1 kg H2	$2.38	$2.56	$2.12	$2.12

Stacking Up Green Competition

CHALMERS UNIVERSITY OF TECHNOLOGY

Maria Grahn

Total cost of ownership (M€/yr). Base case.

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

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

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

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

Methanol shows lowest cost within all fuel categories.

The three methanol production options

	TCO [M€]	Short			Medium			Long		
		ICE	FC	BE	ICE	FC	BE	ICE	FC	BE
	MGO	0.9			1.7			2.4		
Biofuels	Biomethanol	2.0	4.2		3.9	5.7		5.7	7.2	
Biofuels	BioDME	2.3			4.2			6.2		
Biofuels	Biodiesel	2.7			5.2			7.6		
Biofuels	BioLMG	3.0	4.9		5.4	6.8		7.8	8.7	
Biofuels	BioLBG	2.8	4.8		5.1	6.6		7.4	8.4	
Biofuels	HVO	2.4			4.6			6.8		
Bio-electrofuels	E-biomethanol	2.6	4.7		4.9	6.6		7.3	8.5	
Bio-electrofuels	E-bioDME	2.9			5.4			7.9		
Bio-electrofuels	E-biodiesel	3.2			6.2			9.2		
Bio-electrofuels	E-bioLMG	3.6	5.4		6.6	7.8		9.6	10.2	
Bio-electrofuels	E-bioLBG	3.6	5.3		6.5	7.7		9.5	10.1	
Electrofuels	E-methanol	3.3	5.3		6.5	7.8		9.7	10.3	
Electrofuels	E-DME	3.7			7.0			10.3		
Electrofuels	E-diesel	4.3			8.4			12.5		
Electrofuels	E-LMG	4.3	5.9		8.0	8.9		11.8	11.9	
Electrofuels	Ammonia	3.7	5.5		6.9	8.0		10.2	10.6	
	LH_2	4.7	5.3		8.8	8.6		13.0	11.9	
	Electricity			2.8			5.5			8.3

Low

High

Insight 7. Methanol and E-methanol may be the lowest cost option from a TCO perspective in the shipping sector.

Available and Easily Bunkered

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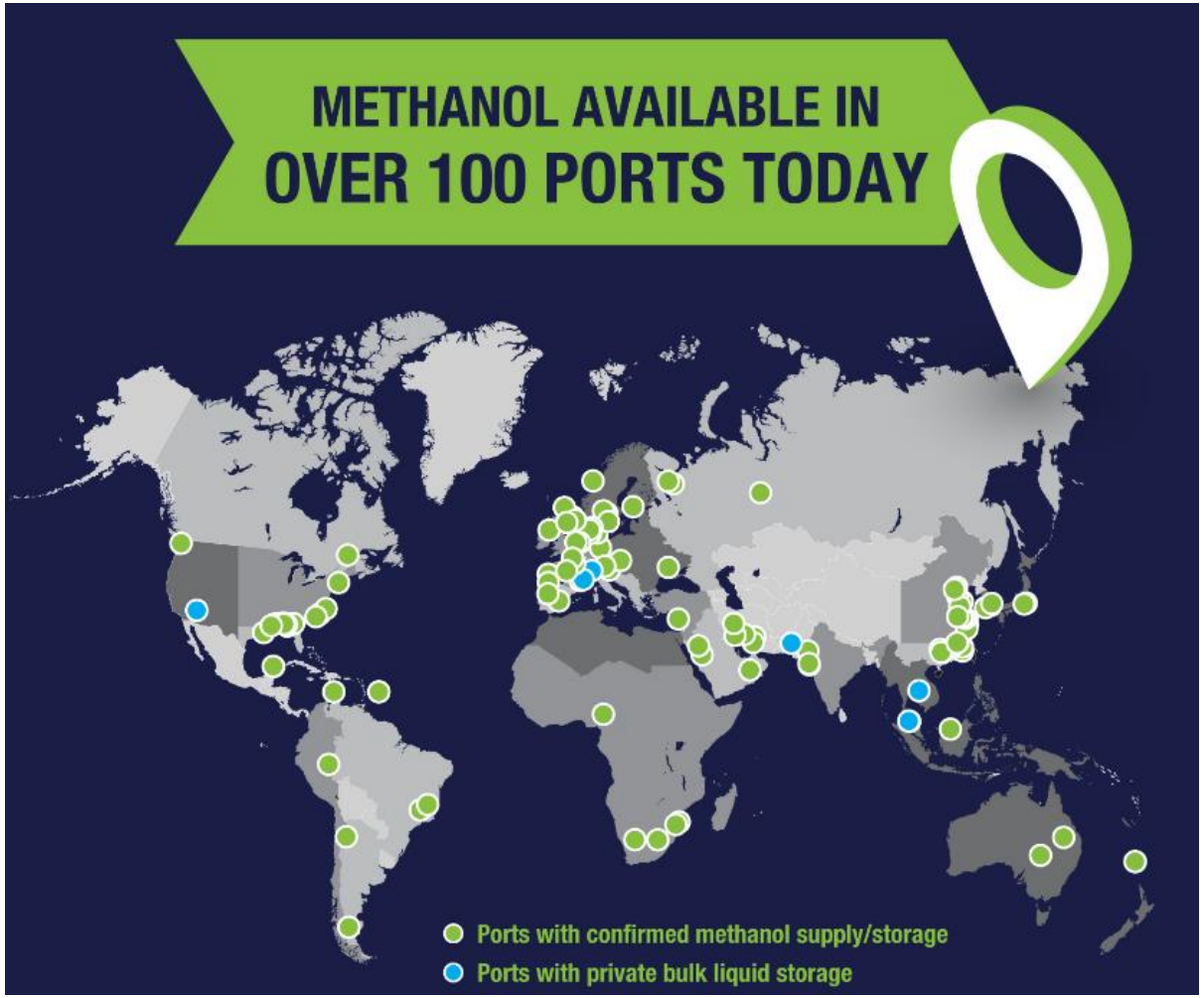
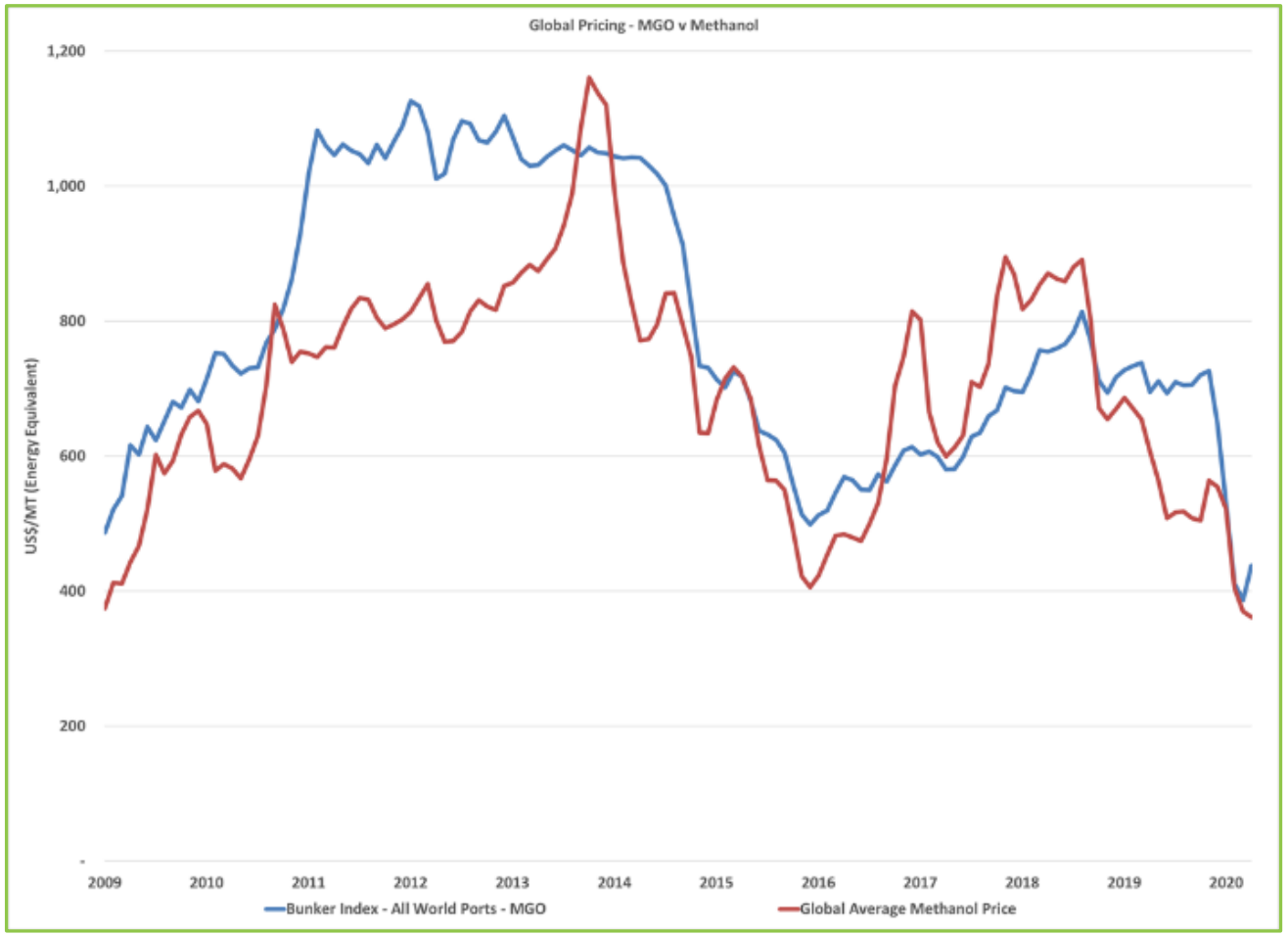


Methanol Barge Bunkering

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

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

Compliance Cost Comparison

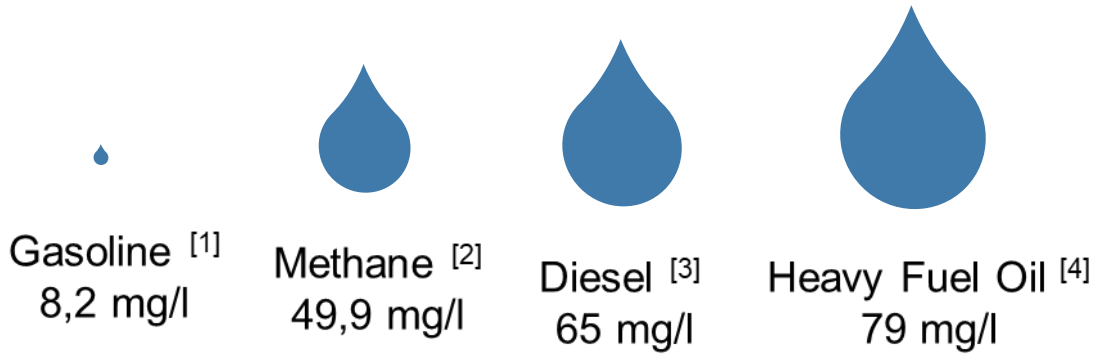


"Methanol is an economically competitive marine fuel over the cycle"

Paul Hexter,
CEO Waterfront Shipping

Pollution in Perspective

LC 50: Lethal Dose: Fish



Gasoline [1] 8,2 mg/l

Methane [2] 49,9 mg/l

Diesel [3] 65 mg/l

Heavy Fuel Oil [4] 79 mg/l

Sources:
[1] Petrobras/Statoil ASA, Safety Data Sheet, ECHA registration dossier Gasoline
[2] ECHA, European Chemicals Agency, registration dossier Methane
[3] ECHA, European Chemical Agency, registration dossier Diesel
[4] GKG/ A/S Dansk Shell, Safety Data Sheet
[5] ECHA, European Chemical Agency, registration dossier Methanol

Methanol [5] 15.400 mg/l

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

Our Contacts

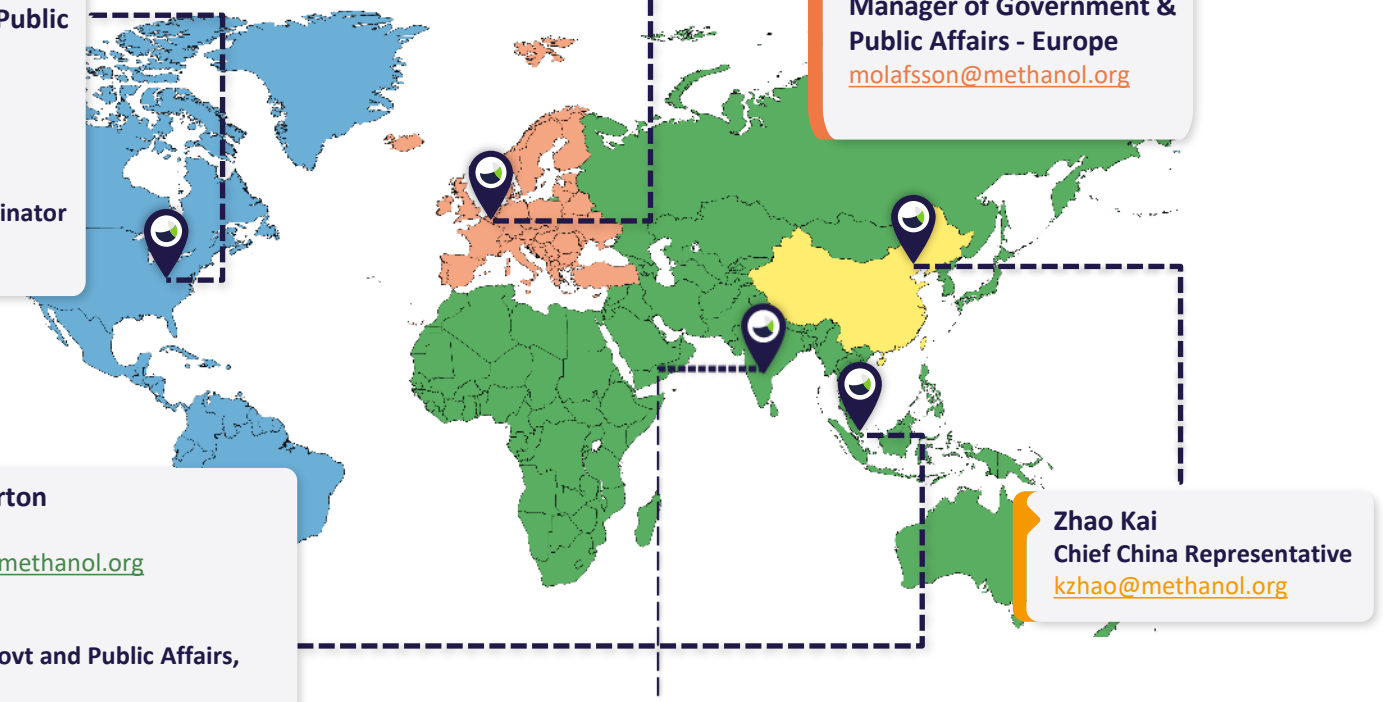
Greg Dolan
CEO
gdolan@methanol.org

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

Nov Bajwa
Operations & Web Media Coordinator
nbajwa@methanol.org

Eelco Dekker
Chief EU Representative
edekker@methanol.org

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



Chris Chatterton
COO
cchatterton@methanol.org

Tim Chan
Manager of Govt and Public Affairs, AP & ME
tchan@methanol.org

Belinda Pun
Executive Manager
bpunr@methanol.org

Zhao Kai
Chief China Representative
kzhao@methanol.org

Prakriti Sethi
India Representative
psethi@methanol.org