METHANOL INSTITUTE

Singapore | Washington | Brussels | Beijing | Delhi

E-Methanol: Production and Markets

Gregory Dolan, CEO

IEA-AMF Annex 64 E-Fuels
10 November 2022

MI History

- The Methanol Institute (MI) was established in 1989
- More than three decades later, MI is recognized as the trade association for the global methanol industry
- We facilitate methanol's increased adoption from our Singapore headquarters and regional offices in Washington DC, Brussels, Beijing and Delhi

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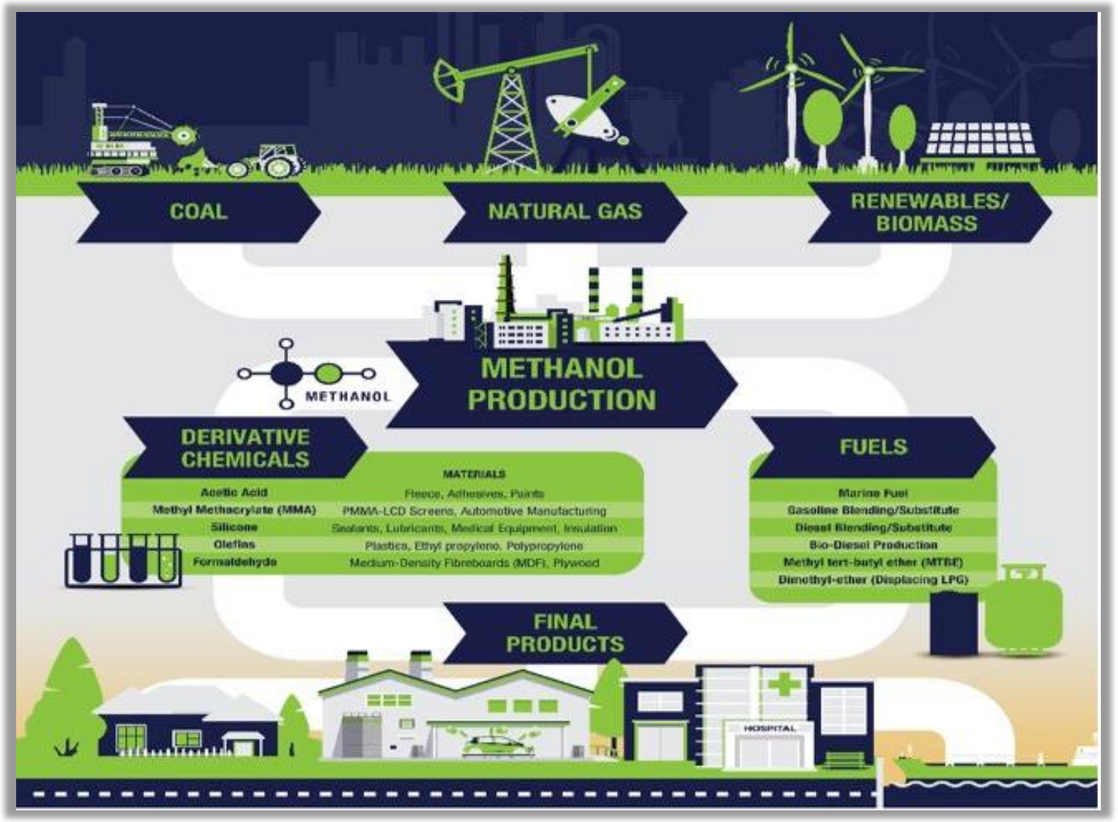
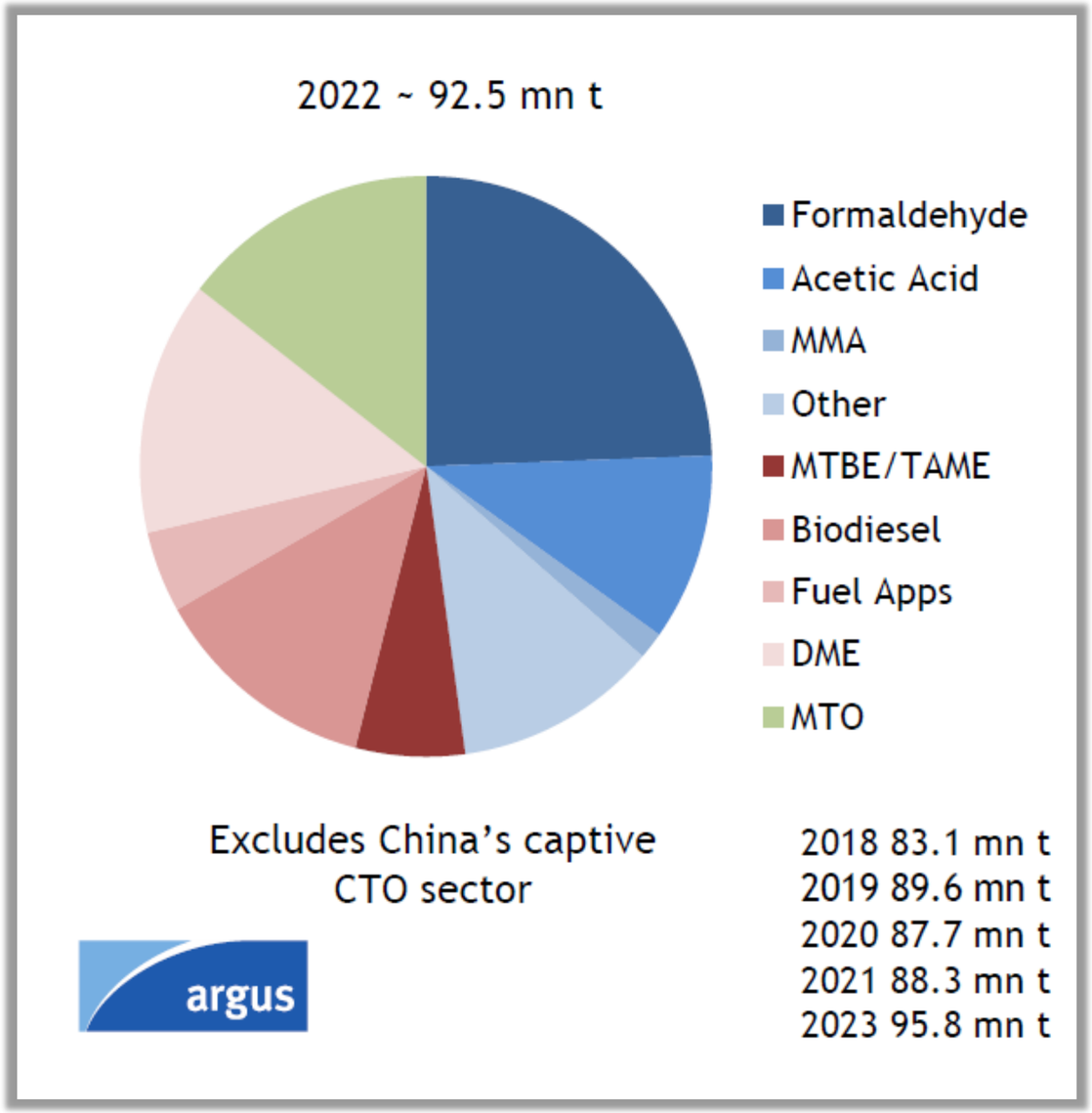
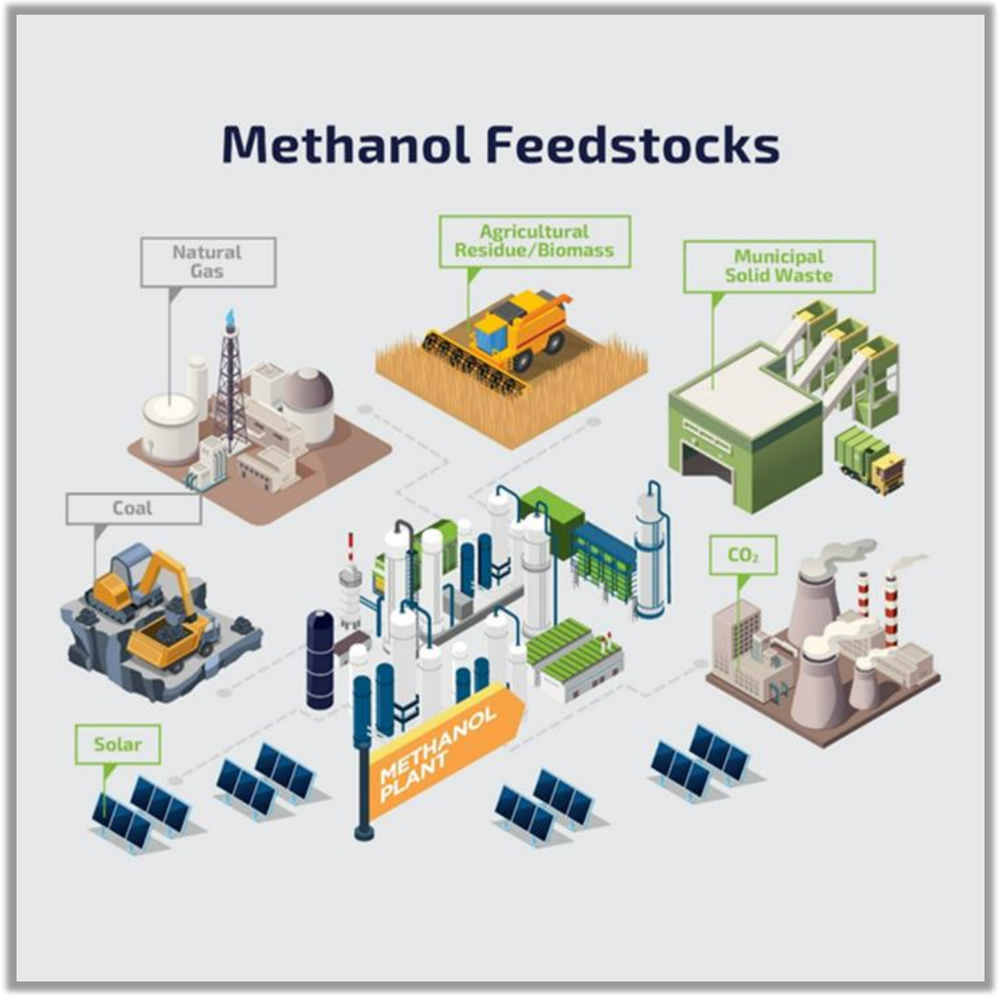
Essential Methanol





Low Carbon and Net Carbon-Neutral



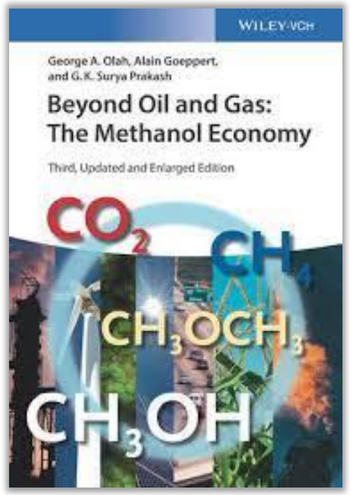
E-Methanol

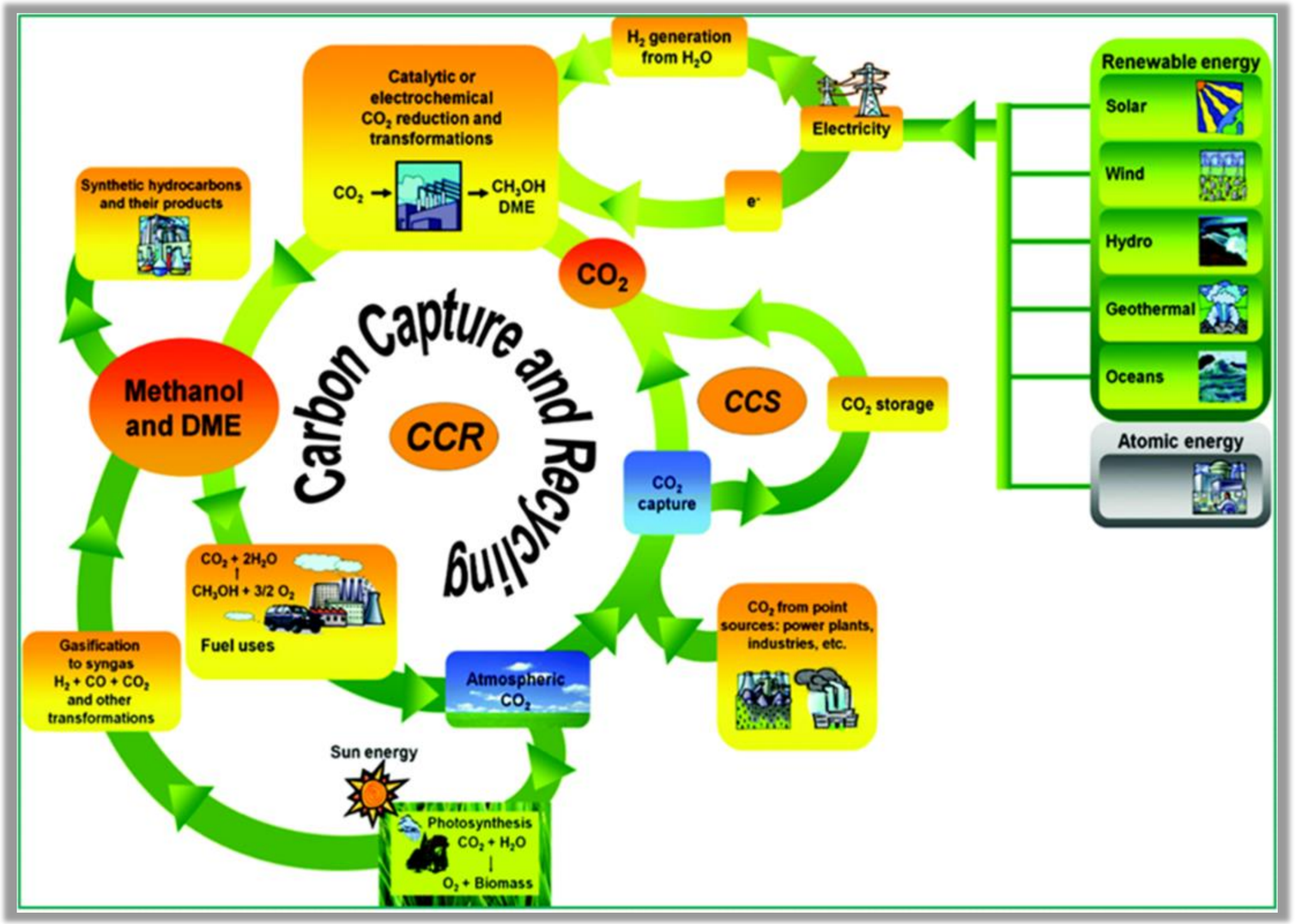
- Feedstocks: green hydrogen and captured CO_2
  - Green hydrogen produced from the electrolysis of water with renewable energy (e.g. solar, wind, geothermal etc.)
  - CO_2 from industrial flue gas (e.g. steel, cement, ethanol), biogenic sources, or direct air capture
- E-methanol is a very-low to net carbon-neutral fuel

Bio-methanol

- Feedstocks: Municipal Solid Waste (MSW), Agricultural Waste, Black Liquor, Bio-Methane from wastewater treatment, landfills, or animal husbandry
- Feedstocks can be gasified or anaerobically digested to produce syngas used in methanol production
- Avoided emissions from landfills, incinerators, or dairy farms potentially allow bio-methanol to be a net carbon-negative fuel

The Methanol Economy

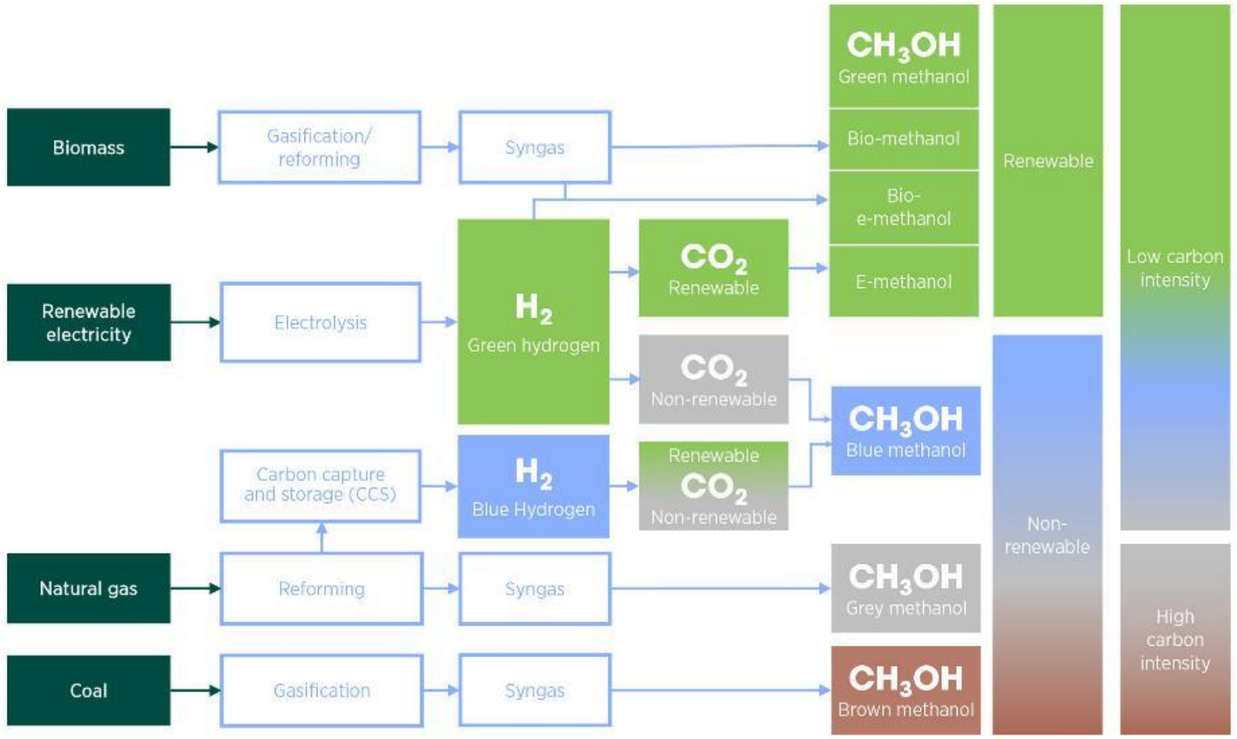




Methanol Color Code

www.methanol.org/renewable/

Figure 2. Principal methanol production routes



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

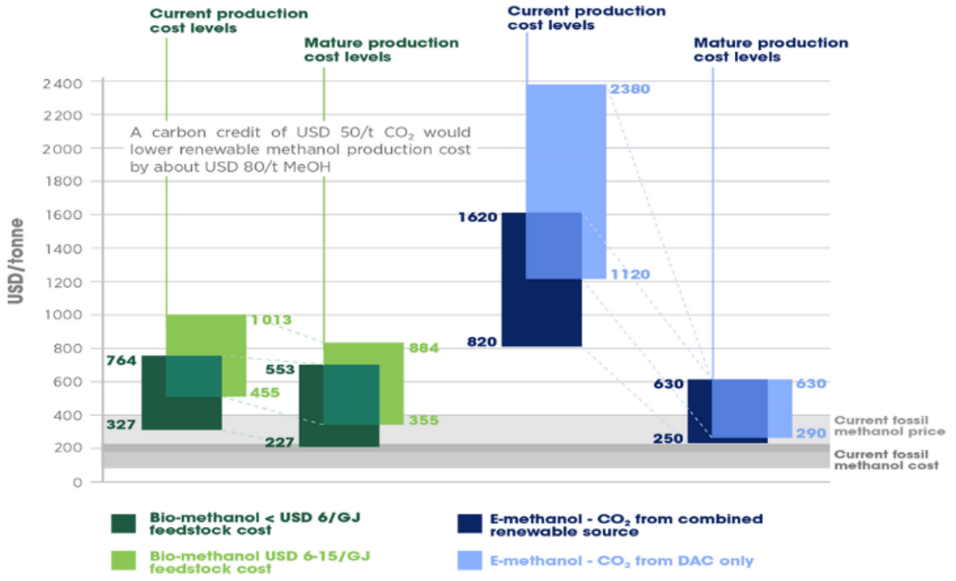
Non-renewable CO_2: *from fossil origin, industry*

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

Renewable Methanol

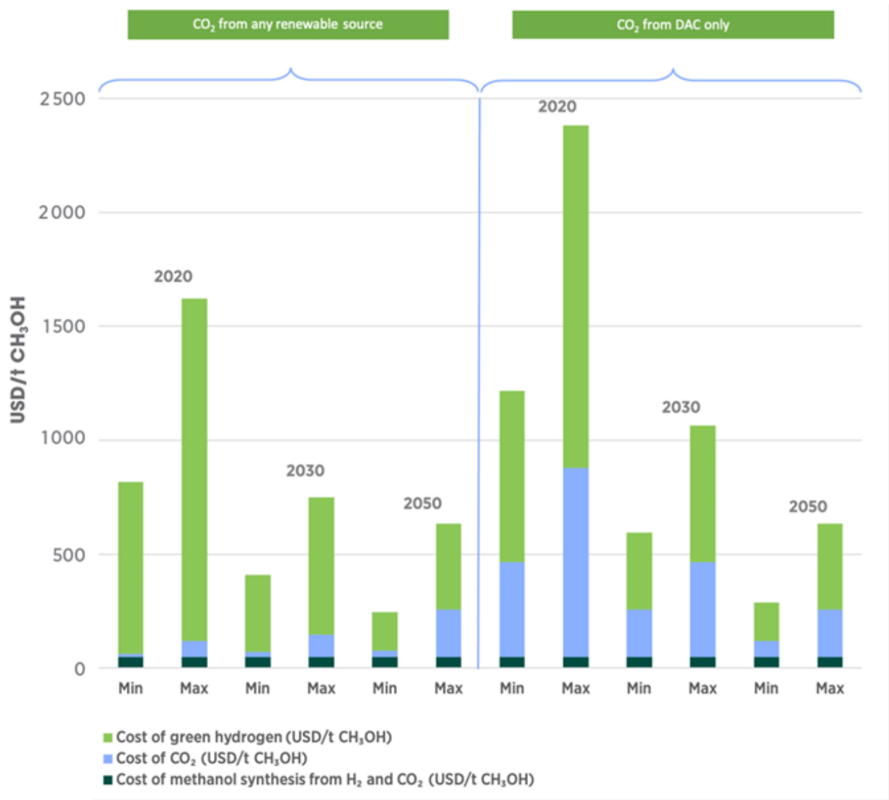
www.methanol.org/renewable/

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.*

Figure 40. Estimated costs of renewable e-methanol up to 2050 depending on the renewable CO_2 source

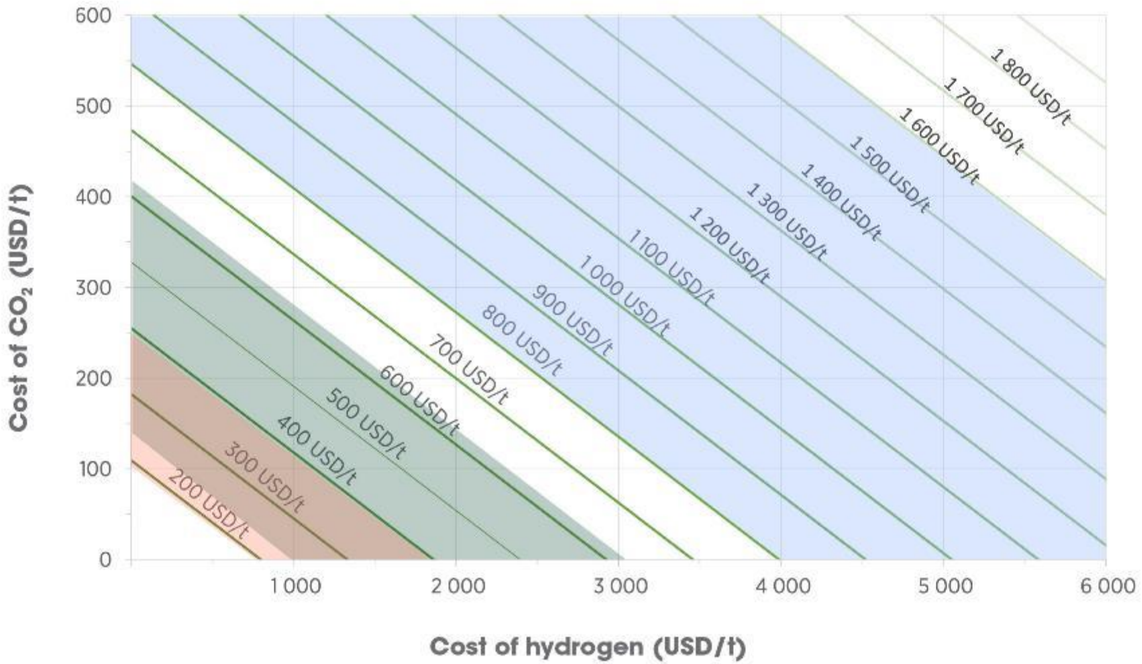


Note: *CAPEX and OPEX for the production of hydrogen and CO_2 are already included in the respective cost of hydrogen and CO_2.*

Renewable Methanol

www.methanol.org/renewable/

Figure 39. Cost of methanol as a function of hydrogen and CO_2 cost

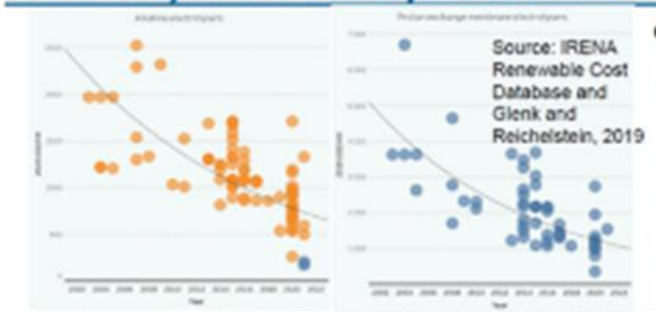


Notes: *Assuming USD 50/t synthesis cost for e-methanol once the raw material H_2 and CO_2 are provided. Estimated cost of e-methanol today and in 2050 can be found in Table 24.*

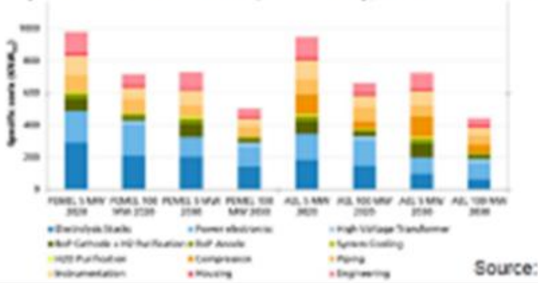
Hydrogen and CO2

www.methanol.org/renewable/

Hydrogen production costs to fall below 1.5 USD/kg: Electricity and electrolyzer cost are be key



Electrolyzers – 800-1200 USD/kW today; USD 500-600 by 2030



Source: FhG ISE, 2022

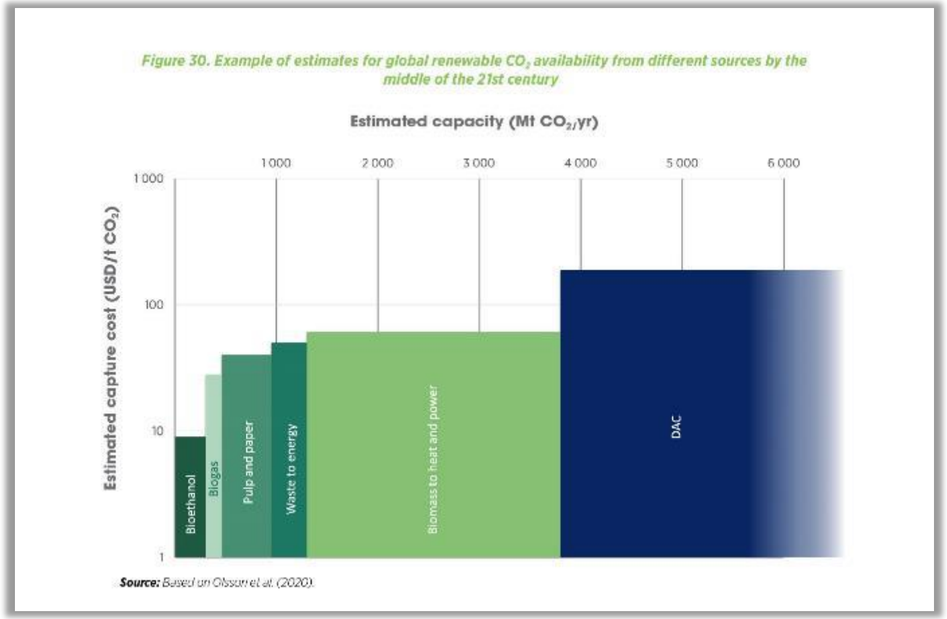
Green hydrogen will become cheaper than blue hydrogen

Source: IRENA (2019)

2050 (1.5C scenario):

- Need to reduce production cost substantially to 1.5 USD/kg hydrogen
- Electrolyzer system costs will fall as deployment increases
- Electrolyzer efficiency may improve to 45 kWh/kg

IRENA



Example biobased industry in Europe: 200-300 Mt recoverable CO_2

IRENA

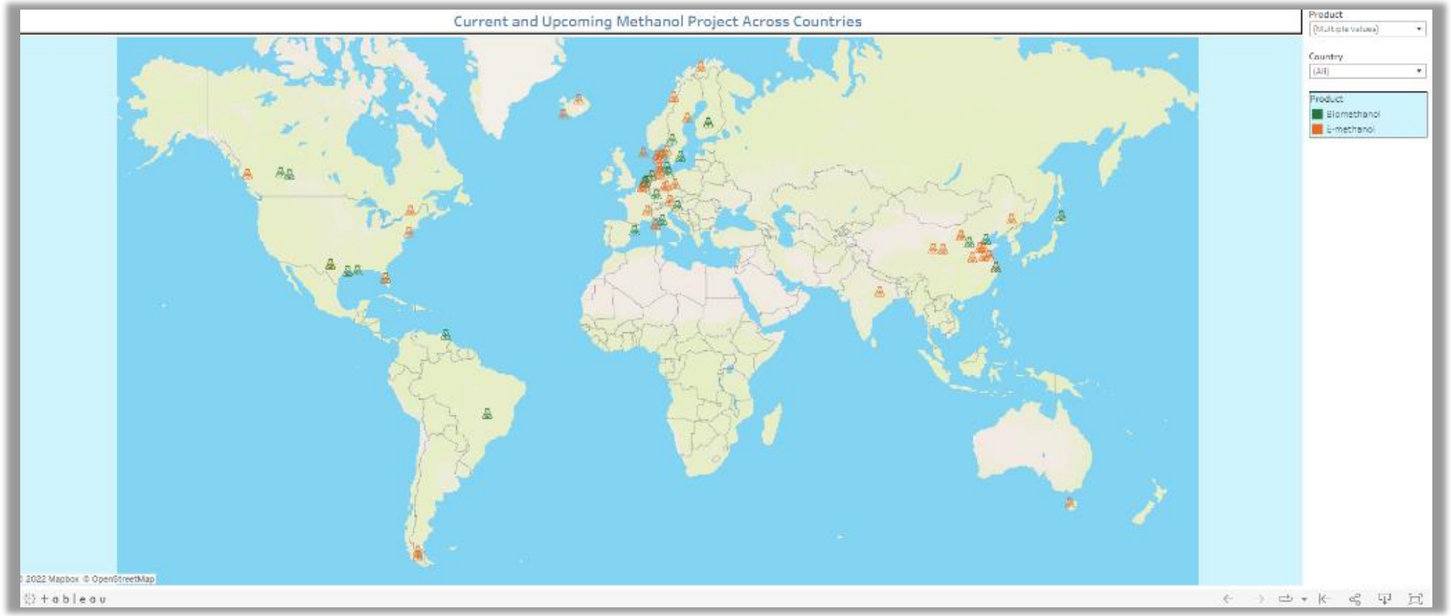
- 569 pulp & paper mills – 50 Mt CO_2
- 528 chemicals plant
- 491 timber mills
- 1100 biomethane units – 5 Mt
- 339 liquid biofuels plant – 5 Mt
- 202 starch & sugar plant
- 147 composites & fibres plant

Additionally

- Power & CHP plant – 50 -100 Mt (Drax etc)
- 450 waste incinerators – 40-120 Mt

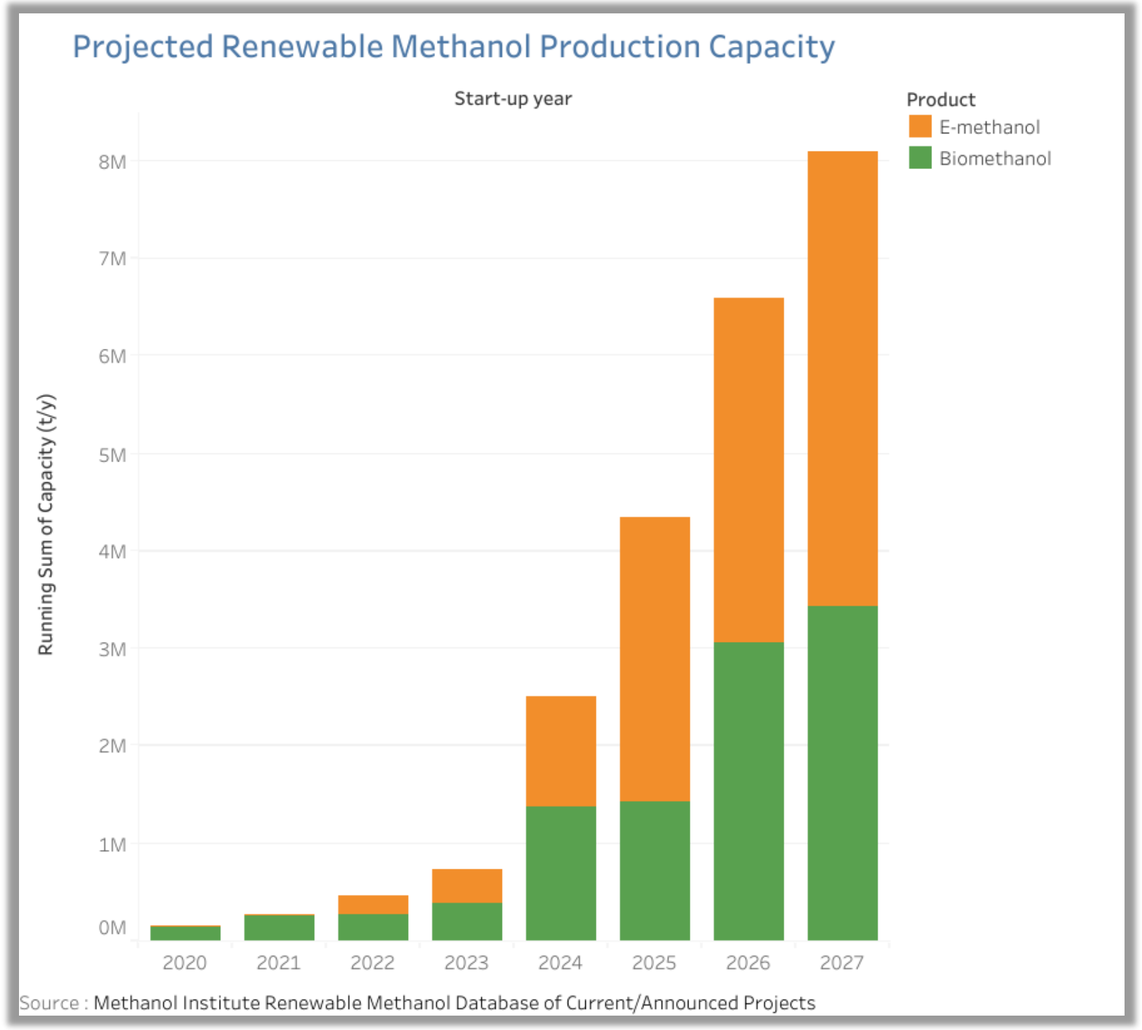
Source: JRC, 2020

Renewable Methanol: *Incoming Wave*



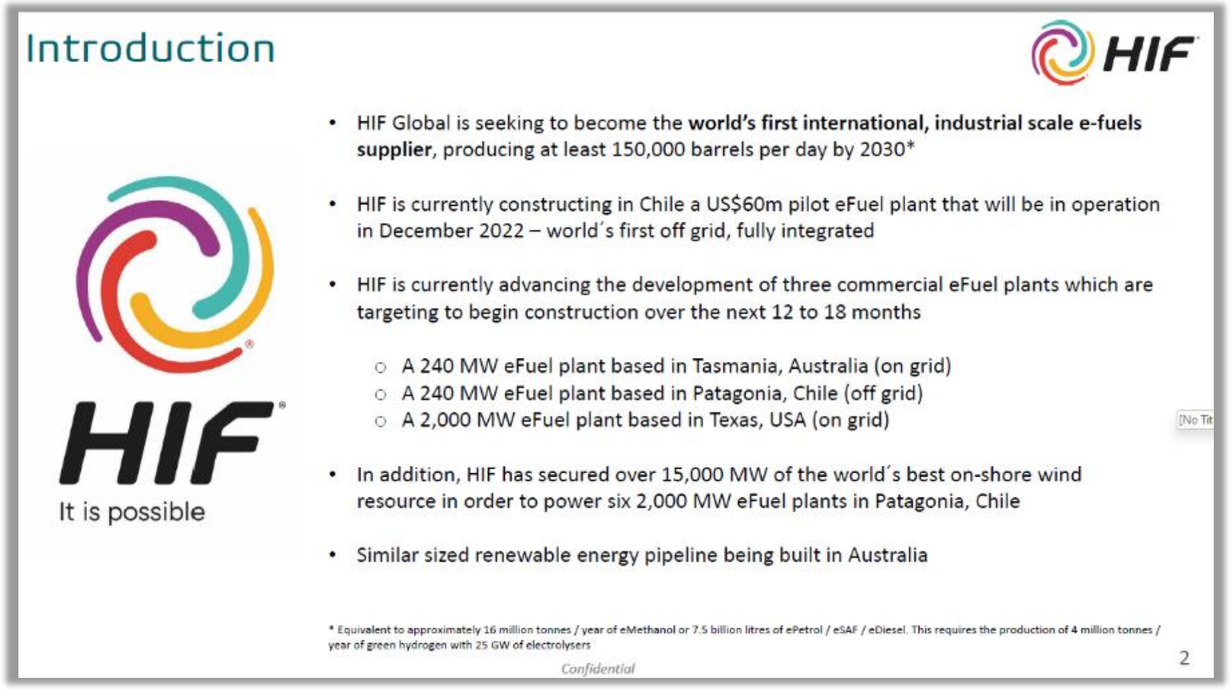
https://www.einpresswire.com/article/594328267/methanol-institute-sees-renewable-methanol-production-growth

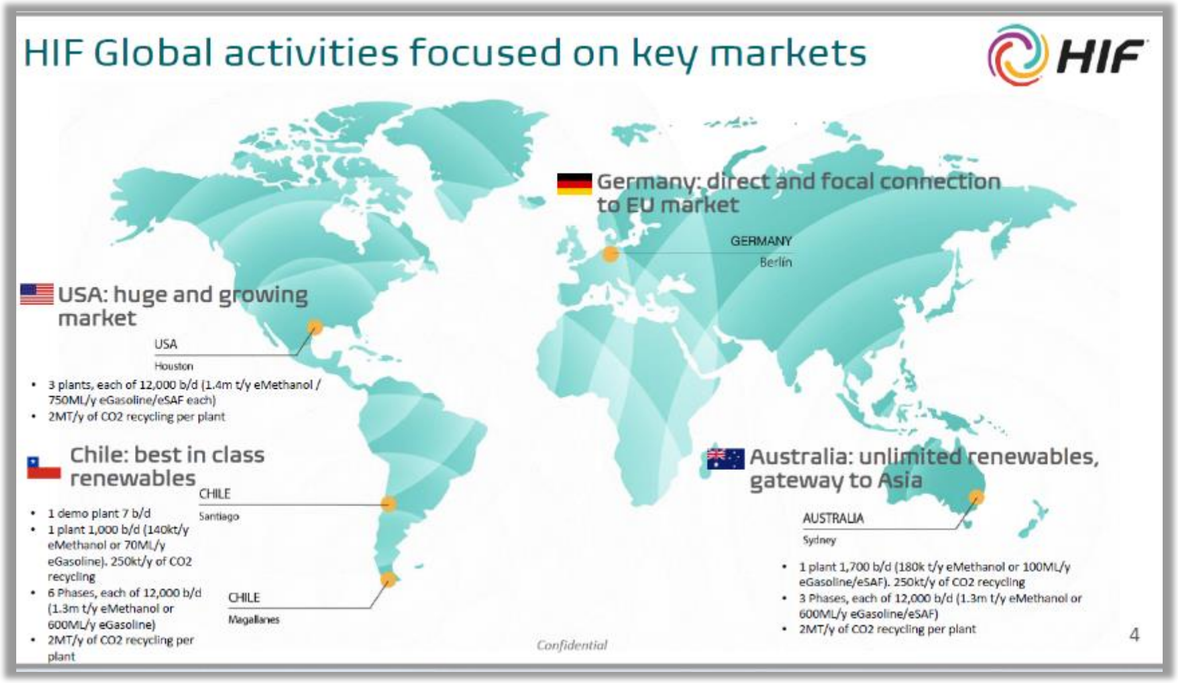
Renewable Methanol: *Incoming Wave*



https://www.einpresswire.com/article/594328267/methanol-institute-sees-renewable-methanol-production-growth

HIF Global





* Equivalent to approximately 16 million tonnes/year of eMethanol or 7.5 billion litres of ePetrol/eSAF/eDiesel. This requires the production of 4 million tonnes/year of green hydrogen with 25GW of electrolysers

Maersk-Spain e-Methanol Agreement

Press releases

Maersk and the Spanish Government to explore large-scale green fuels production

03 November 2022

Decarbonisation | Sustainability | Ocean Transport | Europe | Share

Copenhagen/Madrid – A.P. Moller - Maersk (Maersk) and the Spanish Government have signed a General Protocol for Collaboration to explore the opportunities for large-scale green fuels production in Spain.

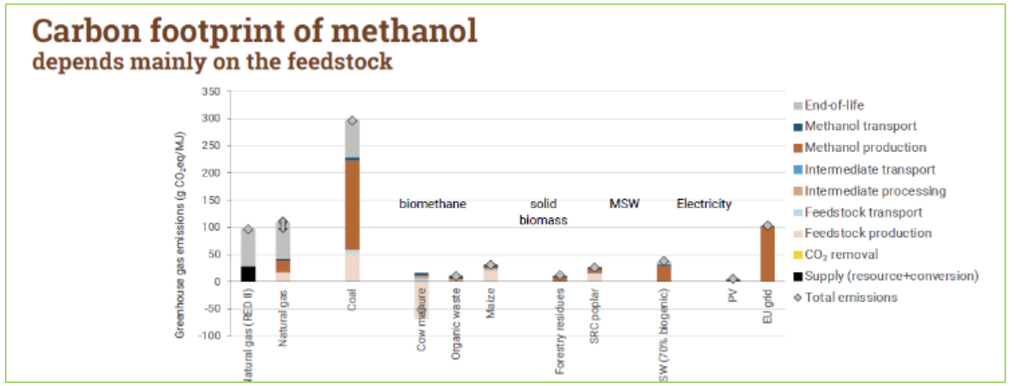
"This project is perfectly aligned with Spain's strategy of reindustrialisation, just transition and the green hydrogen roadmap, advancing in the fulfillment of the common commitment of decarbonisation of the European Union. It will also strengthen economic, political and commercial ties with Denmark, partner and a friend in EU."

Pedro Sánchez
President of the Government of Spain

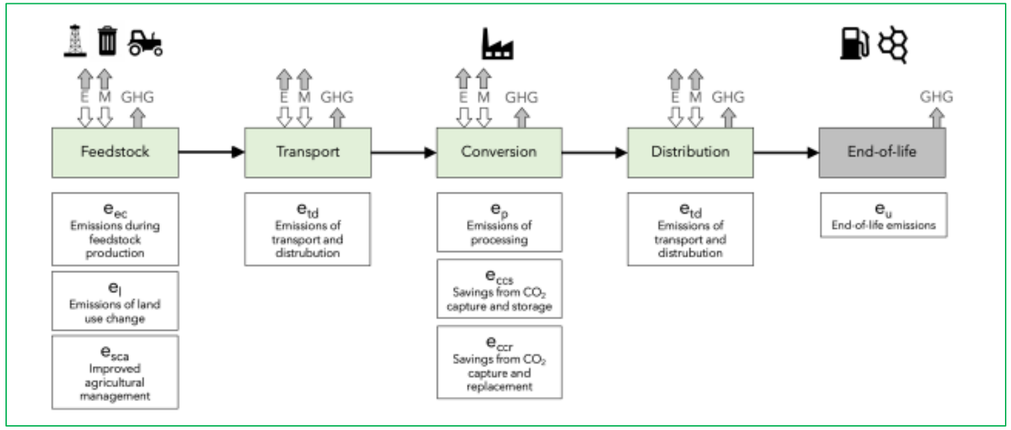
- 03 Nov 2022: Maerk signs agreement with Spain to produce up to two million tonnes of e-methanol a year in Spain by 2023 to supply its fleet of cargo ships and reduce its carbon footprint.
- The project will require and investment of about 10 billion euros partly financed with EU recovery funds, according to Spanish government calculations, and Spain may enter as a strategic investor.
- The parties have carried out a preliminary study on the competitiveness of the project and will now work on a final report by the middle of next year. The development is planned in three phases, with an initial 200,000 tonnes of green methanol being reached in 2025, increasing production to 1m tonnes in 2027 and ultimately 2m tonnes by 2030.
- *https://www.maersk.com/news/articles/2022/11/03/maersk-and-the-spanish-government-to-explore-large-scale-green-fuels-production*

Carbon Intensity Accounting

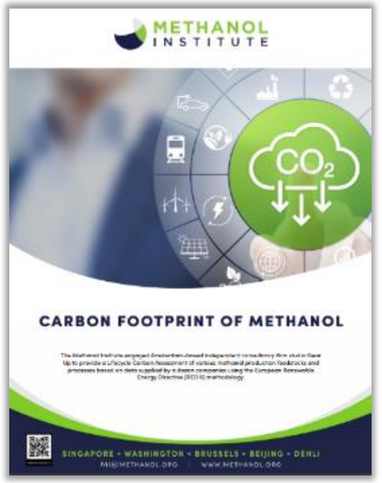
- In January, MI released a report from Amsterdam-based consulting firm studio Gear Up on “Carbon Footprint of Methanol”
- Depending on feedstock and production process methanol’s carbon footprint can be reduced by 65-90%
- In May, International Methanol Producers and Consumers Association working with sGU released a “backpack” calculator can help determine the carbon footprint of methanol depending on feedstock, conversion technologies, and the fate as either fuel or chemical
- ***Call to Action: MI and IMPCA working together assist the methanol industry in developing a common platform for carbon intensity accounting***

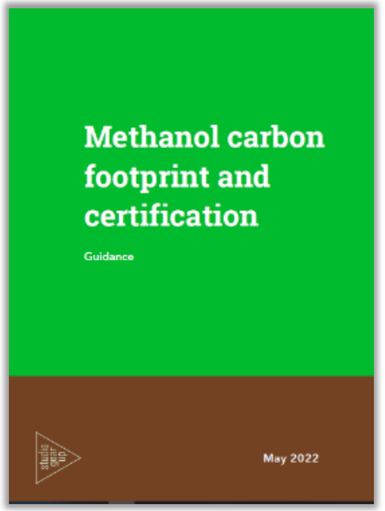


https://www.methanol.org/policy-initiatives/europe/



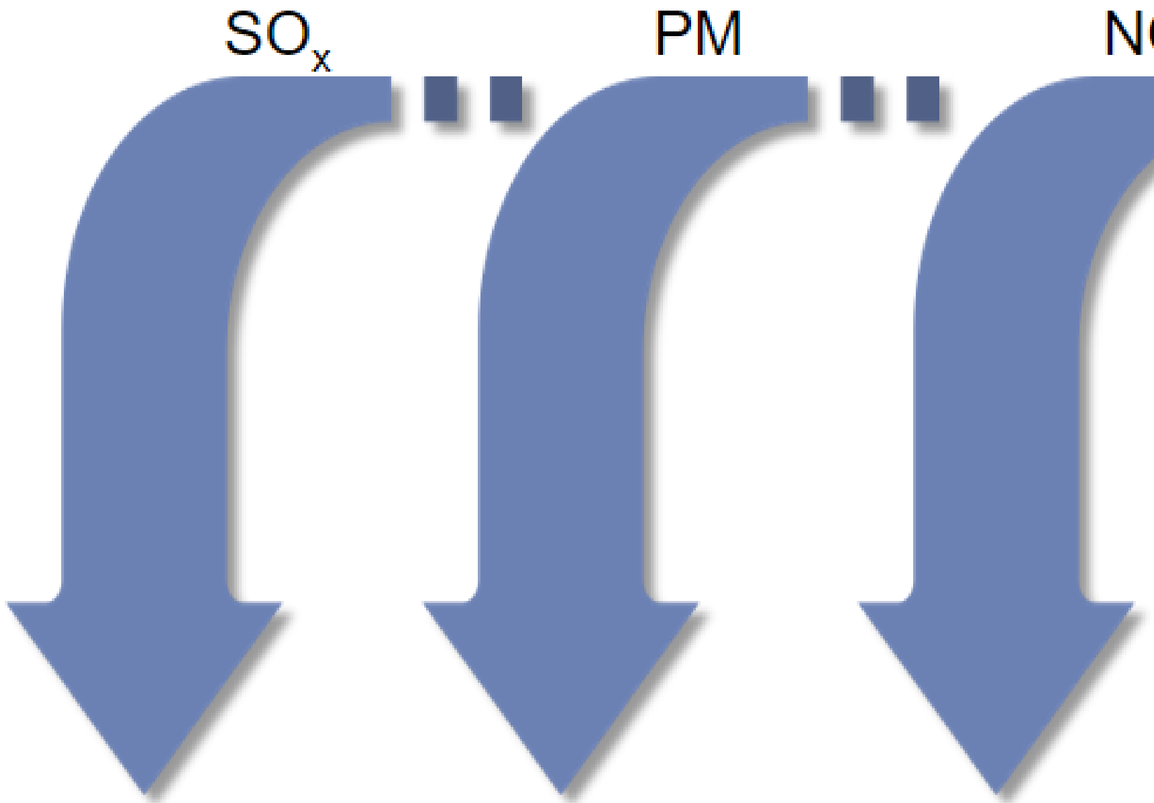
https://www.impca.eu/IMPCA/Technical/IMPCA-Documents





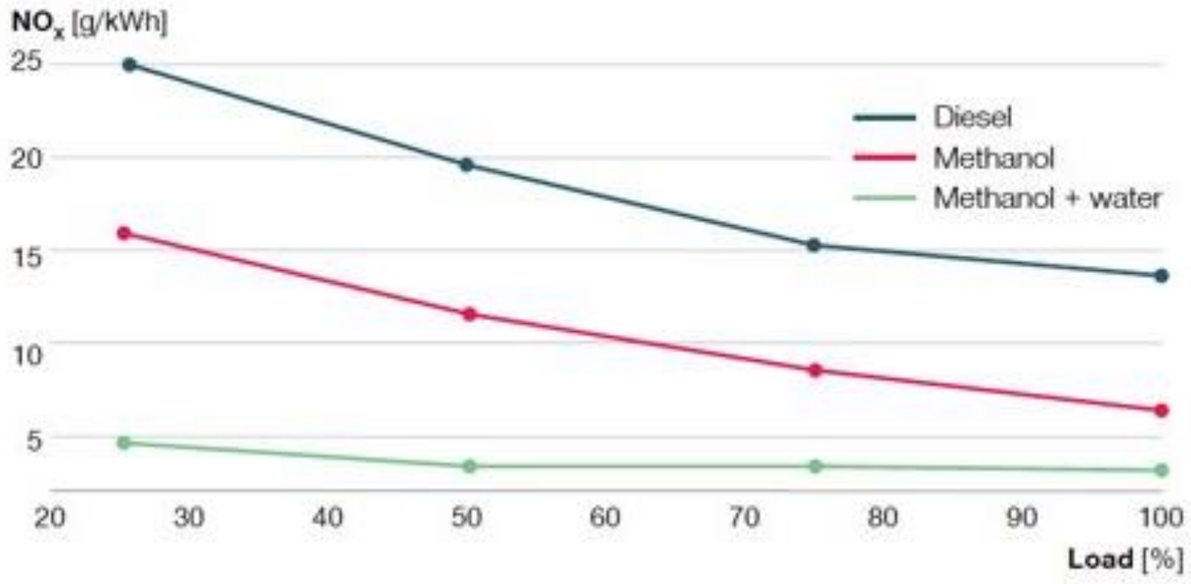
Improving Local Air Quality

Emission reduction potential:



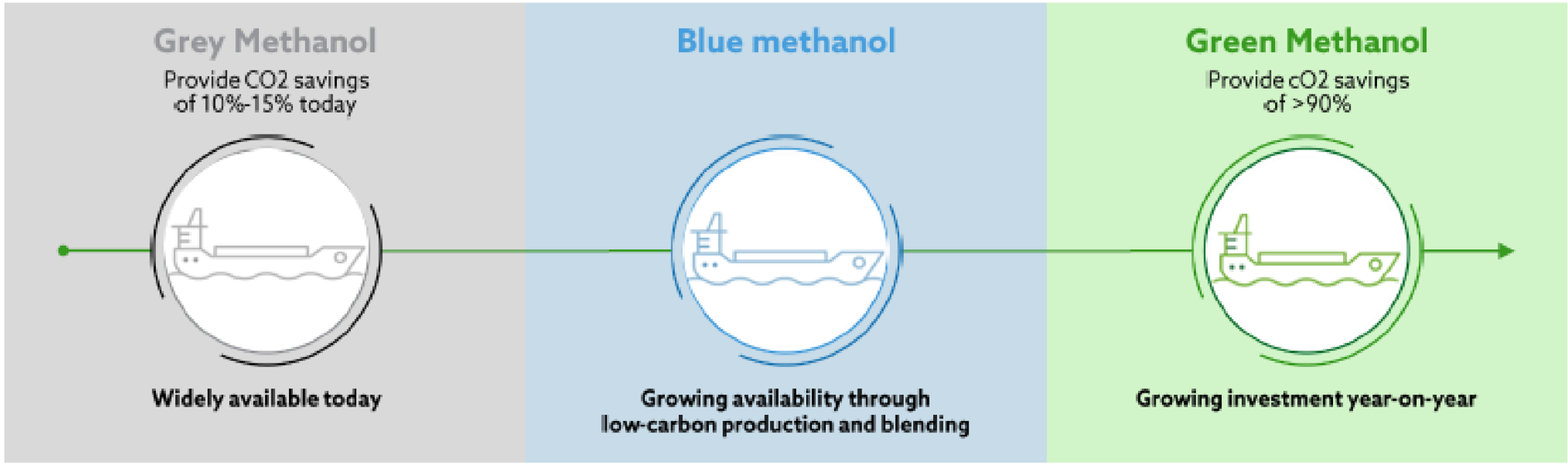
source: Stena Line

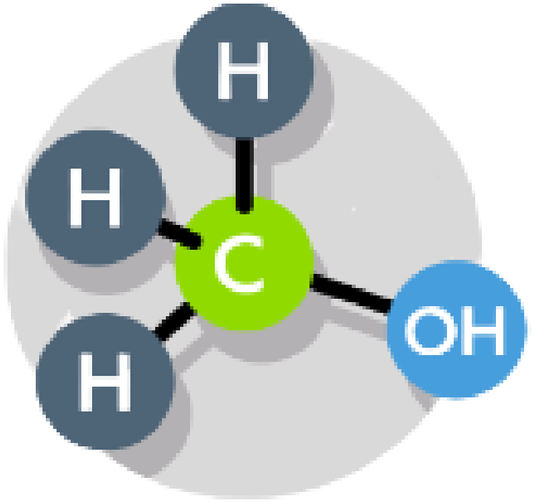
source: Stena Line



source: MAN ES

The Methanol Molecule





- Methanol molecule is the same energy and chemical characteristics no matter how it is produced
- Completely fungible from grey to blue to green facilitating blending with reduced carbon intensity as low carbon and net carbon-neutral supply grows
- Methanol runs well in existing engines with few modifications and significantly lower CAPEX when compared with other available alternative fuels

Marine


SUPERGREEN
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Methanol Making Headlines

METHANOL INSTITUTE

Maersk spends $1.4 billion on ships that can run on 'carbon neutral' methanol

KEY POINTS
* Maersk says vessels will be built by South Korea's Hyundai Heavy Industries and have capacity to carry around 16,000 containers.
* According to the International Energy Agency, in 2019 international shipping was

OCI signs MoUs to develop ammonia and methanol as shipping fuels

Author: Richard Ewing

2021/03/09

MethaShip 'fuel with

NEWS PROVIDED BY Methanol Institute October 22, 2018, 14:46 GMT

Damen introduces offshore vessel design with methan option

by Mariska Buitendijk | Jan 27, 2020 | News | 0 comments

IMO guidelines on use of methanol as a marine fuel to boost demand

MSC explores Methanol fuel

Mediterranean Shipping Company (MSC) and the German drybulk shipowne Oldendorff Carriers will join the Methanol Institute (MI) in order to boost dec

July 20, 2021 6:09 pm

German ship

Chinese Study Examining Methanol as a Marine Fuel

July 14, 2020

Vopak

NEWS: first barge-to-ship methanol bunkering operation in the world

Waterfront Shipping takes leadership role in demonstrating simplicity of methanol bunkering to marine

Cargill in order talks for first-ever methanol-fuelled bulkers

Ocean transportation president Jan Dieleman says Global Maritime Forum discussions on carbon-cutting gives the confidence to say, 'Let's go for it'

3 October 2022 12:14 BST UPDATED 3 October 2022 18:30 BST

COSCO Orders 12 Ultra-Large, Green Methanol Containerships for $2.9B

COSCO will invest $2.9 billion for methanol dual-fuel ultra-large containership (COSCO)

PUBLISHED OCT 28, 2022 4:17 PM BY THE MARITIME EXECUTIVE

Stena Line RoPax is world's first vessel to use recycled methanol as fuel

Written by Nick Blenkey

Rolls-Royce And Lurssen To Focus On Methanol Propulsion For Large Yachts

l: An accessible early an shipping

Methanol is key solution for shipping decarbonisation today, research suggests

TRANSITION

MAERSK Prices Book Tracking Schedules

Press releases

Maersk secures green e-methanol for the world's first container vessel operating on carbon neutral fuel

16 August 2021

Denmark Europe Decarbonisation Sustainability

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Dutch shipyards investigate sustainable fuel alternative

Dutch maritime companies, including superyacht builders, Green Maritime Methanol project...

Norwegian Cruise Line Holdings Proceeding with Methanol Tests

Norwegian Cruise Line discussed its future fuel plans during the premier of Norwegian Prima in New York (NCL)

PUBLISHED OCT 12, 2022 5:14 PM BY THE MARITIME EXECUTIVE

RUSSIA, JAPAN TO ... WITH DUAL-FUEL E...

By Baird Maritime - September 9, 2021

Methanol Engine... with Major Order...

Dual-fuel fuel-mix in newbui...

Contracting in kW

LNG LPG Ethane Methanol Ammonia

OOCL will add seven methanol dual-fuel container ships to its fleet (source: OOCL)

Methanol newbuilds elbow LNG out of the spotlight in October

08 Nov 2022 by John Snyder

...s from the global maritime ...arine fuel highlighting it as

Proman Expands to Six Order f... Methanol-Fueled Tankers

Oslo: The first three vessels to use DNV GL... will be a series of 50,000 dwt tankers order...

Milesto... Dual-F...

A.P. Møller-... empowerin...

Hyundai's Ship-Building Division, HHI-SBD, has ordered 8 × MAN B&W 8G95ME-LGIM (-Liquid Gas Injecti... Methanol) engines in connection with the building of 8 × 16,000-teu container ships for A.P. Møller – Maersk global integrator of container logistics.

Hyundai Engine & Machinery Division, HHI-EMD, will build the engines. The order contains an option for a f...

Rul... of Methanol Fuelled Ships.

PUBLISHED OCT 18, 2022 11:26 AM BY THE MARITIME EXECUTIVE

By MAN Energy Solutions

RULES MARINE & SHIPPING

icct THE INTERNATIONAL COUNCIL ON Clean Transportation

A step forward for "green" meth... and its potential to deliver deep... reductions in maritime shipping

Posted Wednesday, 1 September 2021, 13:47

Abigail Martin

The shipping industry is under increasing pressure from regulators and consumers to

PRINT

As the shipping industry fights to reduce both sulphur oxide emissions and carbon footprint, methanol and ethanol have been identified as good potential fuel alternatives in achieving this goal, according to a study published by the European Maritime Safety Agency (EMSA).

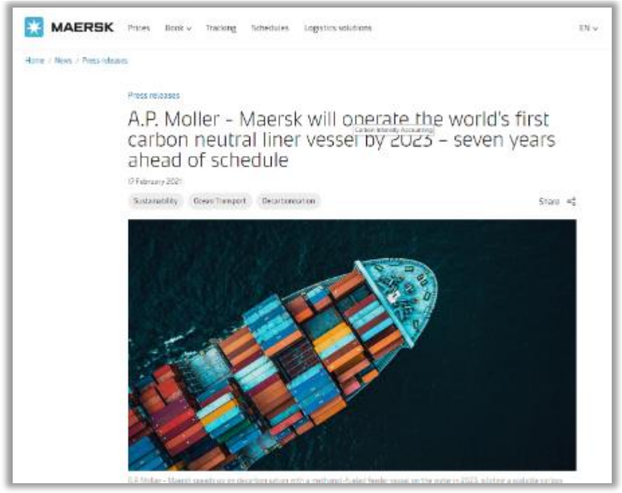
The use of alternative fuels in the shipping industry has been receiving increasing attention as a method of complying with low sulphur requirements for fuels and reduced emissions of sulphur oxides. As methanol and ethanol are sulphur-free, they would ensure compliance with the European Commission Sulphur Directive.

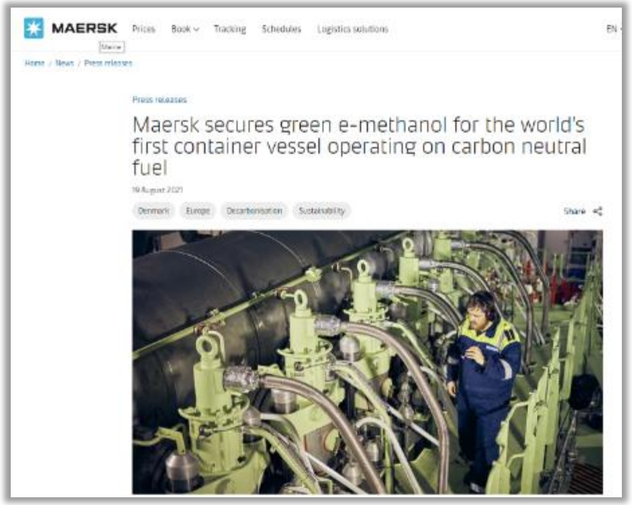
Related news

Premium

www.methanol.org/join-us

Game Changer 1: Maersk Vessel Orders

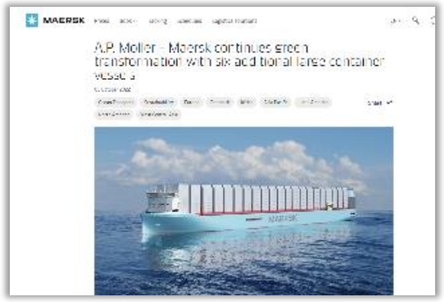




"The reason that we have gone for methanol on the first one is that it is the most mature from the technology perspective; we can get an engine that can burn it." Morten Bo Christiansen, head of decarbonization at Maersk

"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

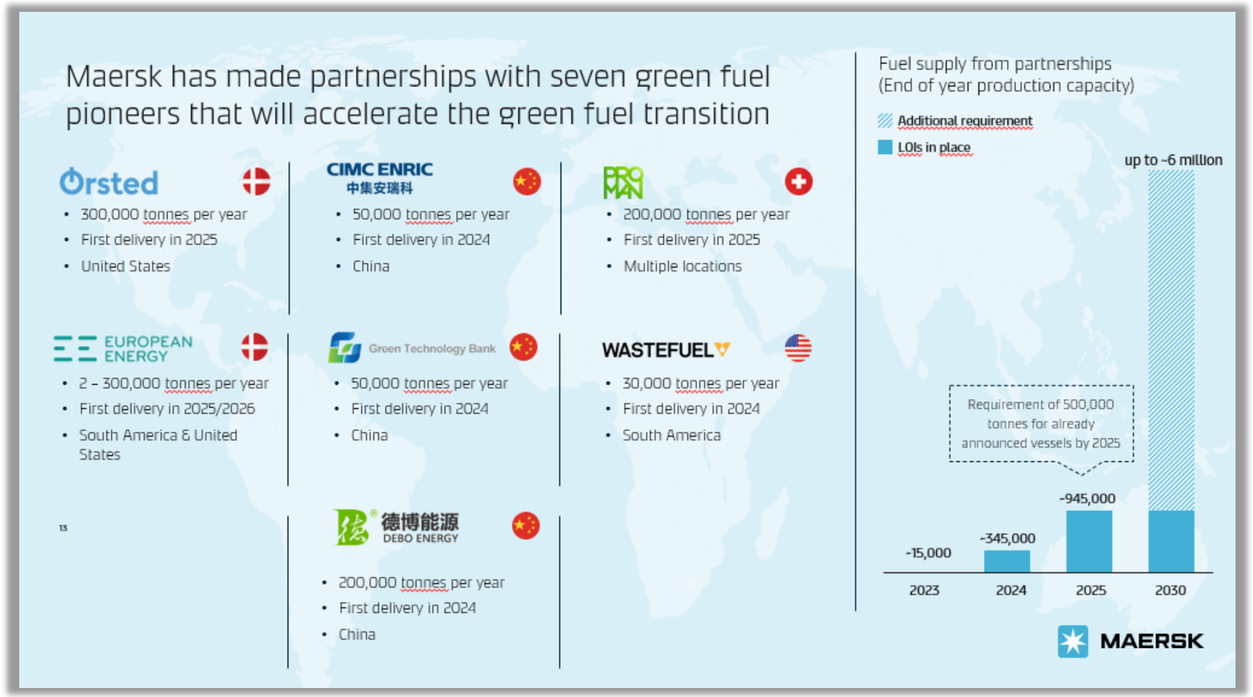
https://www.maersk.com/news/articles/2022/10/05/maersk-continues-green-transformation



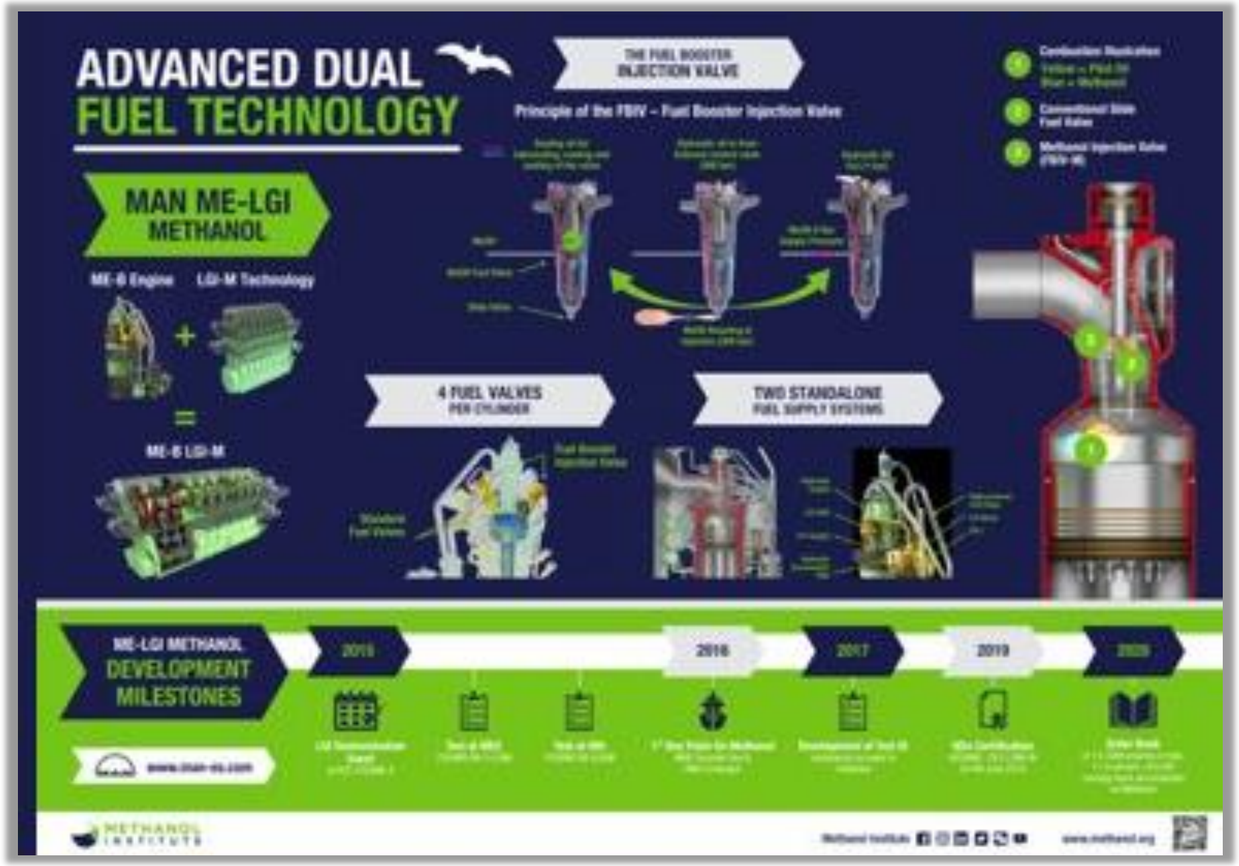
- **21 Feb 2021**: Maersk announces that the world's first carbon neutral container vessel by 2023 will operate on dual-fuel methanol
- Maersk has now ordered 2,100 TEU methanol dual-fueled feeder vessels from Korean shipyard
- **24 Aug 2021**: "Maersk accelerates fleet decarbonization with 8 large ocean-going vessels to operate on carbon neutral methanol"
- 16,000 container (Twenty Foot Equivalent – TEU) vessels
- $1.4 billion order each vessel $175 million 10-15% more expensive
- ***5 Oct 2022:*** Maersk orders additional six 17,000 TEU methanol dual-fuel vessels, in total now ordered 19 vessels to be delivered by 2025
- ***Each ship will require 35,000-40,000 tons of methanol annually or a total of 500,00 tons of methanol***
- *Customer Pull:* Maersk's 200 largest customers asking for carbon neutral transport

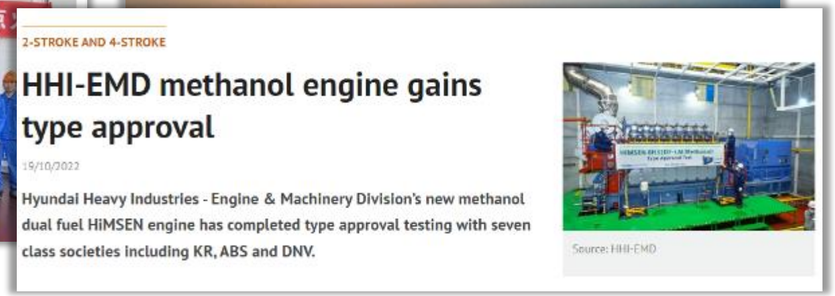
Game Changer 1.1: Maersk Methanol Supply

- **10 March 2022**: Maersk announces strategic partnerships with six leading companies -- including MI members Proman and Wastefuel -- with the intent of sourcing at least 730,000 tons/year of green methanol by end of 2025
- **19 August 2022:** Maersk announces additional bio-methanol supply partnership with China's Debo
- Maersk estimates will need 6 million tons of renewable methanol by 2030 to fuel 25% of their 700-vessel fleet



Engines Available and More Coming



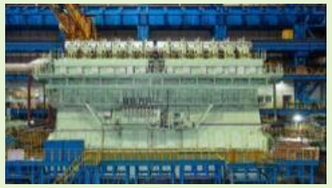


Since 2016, MAN has received orders for 72 large, two-stroke methanol engines, with 19 already in operation in chemical tankers operated by MI members. Another 118 orders on the way!!!

On the Water and On the Way

METHANOL INSTITUTE







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Methanol Fuelled Vessels on the Water and on the Way

To learn more about each project, click on the project title.

Sweden (2015):

One of the world's largest ropax ferries - Stena *Germanica* - has been operating on methanol fuel since 2015.

Canada (2016-2019):

Methanex Waterfront Shipping and their partner vessel operators - Mitsui OSK Lines, Westfal-Larsen, Marinvest, IINO, and NYK Group - began operating a fleet of 11 50,000 dwt chemical tankers with dual-fuel methanol engines.

Germany (Jul 2018):

Shipowner SAL Heavy Lift to install FUELSAVE hydrogen/methanol injection system in 6 vessels

Germany (Mar 2019):

Abeking & Rasmussen shipyard designing "green cruise" concept vessel using methanol fuel cells for hotel load and methanol propulsion engines

Netherlands (Jan 2020):

Damen Shipyards has developed a new concept Offshore Support Vessel (OSV) to operate on methanol

Germany (Jan 2020):

Shipowner Liberty One has ordered a new multipurpose (MPP) ship powered by methanol






MI@methanol.org | www.methanol.org

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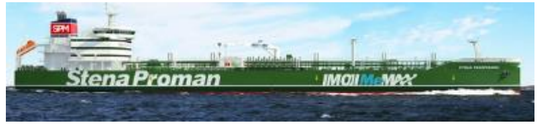
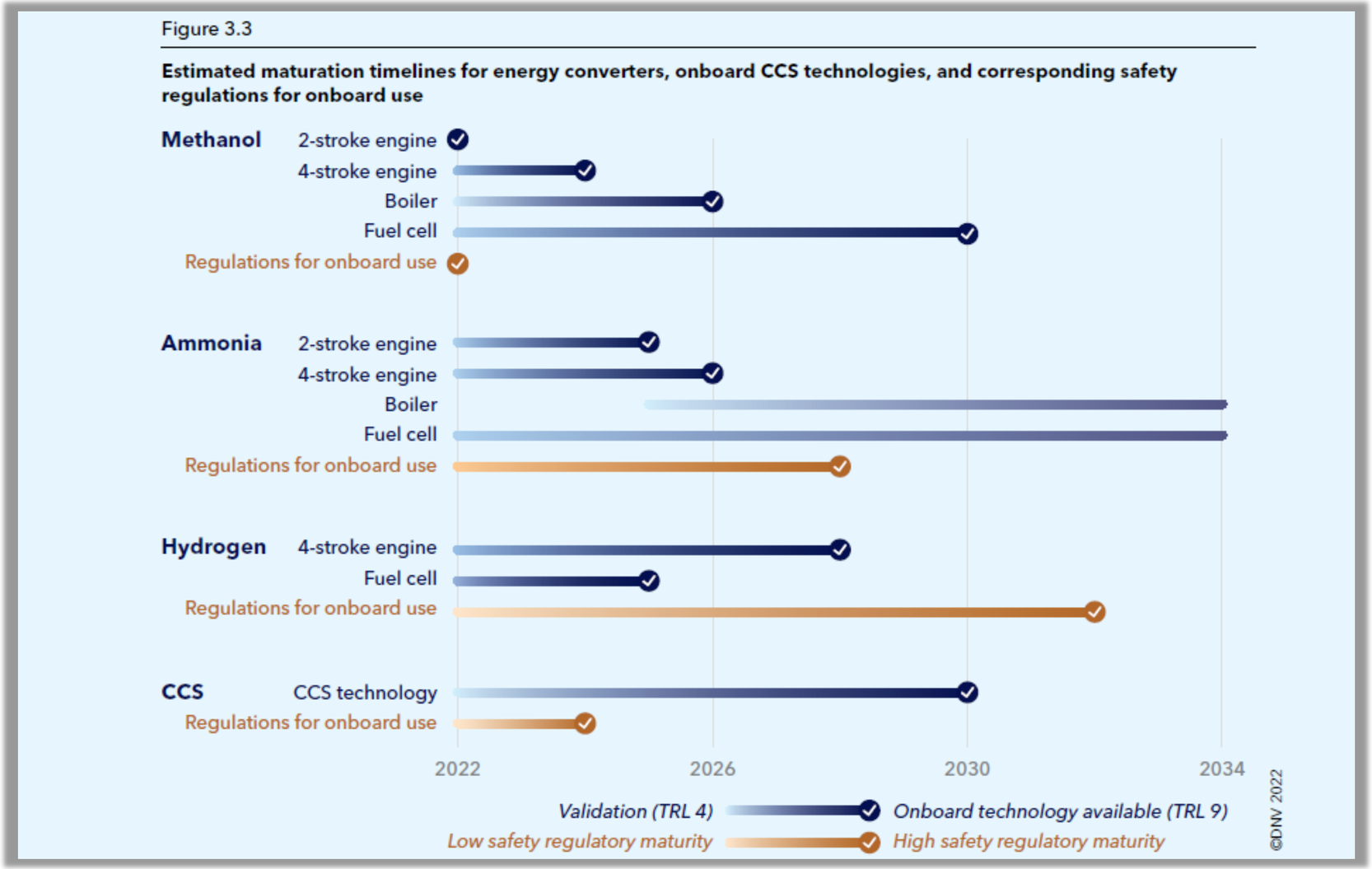




Technology Readiness



https://www.dnv.com/maritime/publications/maritime-forecast-2022/index.html

- Methanol has a high TRL and approved IMO safety standards
- Methanol does not require basic engine research and development
- Methanol needs more vessels on the water, bunkering solutions, and fuel production

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.

Road Transport

China M100 Cars

- M100 taxi numbers continue to grow in Gui Yang and Shanxi will be the next province for future growth
- All the M100 vehicles are China VI emission standard (equivalent to Euro 6 with additional formaldehyde and unburnt methanol certifications)
- In 2022, Geely began selling methanol ICE/electric hybrid
- The hybrid car reduces M100 fuel consumption from 13.6 to 9.3 L/100km, a fuel economy of less than 30 cents RMB (USD$0.043)/km
- MIT Technology Review *"China is betting big on another gas engine alternative: methanol cars"* https://www.technologyreview.com/2022/09/30/1060508/china-betting-methanol-cars/

Methanol Fueled Vehicles in China (by Sept. 2022)

Province	City	Vehicle Type	Vehicle No.
Shanxi	Jinzhong	Taxi/service	130
	Tai Yuan	Passenger car	3
	Xin Zhou	Passenger car	12
	Yun Cheng	Taxi	14
Shannxi	Xi'An	Taxi	8,124
	Bao Ji	Taxi	585
		Mini MPV	15
	Yu Lin	Self-Dumping Truck	5
	Han Zhong	Taxi	20
Guizhou	Gui Yang	Taxi/private	17110
	Tong Ren	Taxi	239
	Bi Jie	Taxi	100
Gansu	Ping Liang	Taxi	150
He Long Jiang	Wu Chang/Harbin	Taxi	48
Xin Jiang		HD Truck	1000
		Total	27555

[1] https://www.miit.gov.cn/datainfo/dljdclscqyjcpgg/pamoosn/art/2022/art_e29ab6828d7e49029d8b660233d8ea79.html

[2] https://dh.geely.com/ssilm1

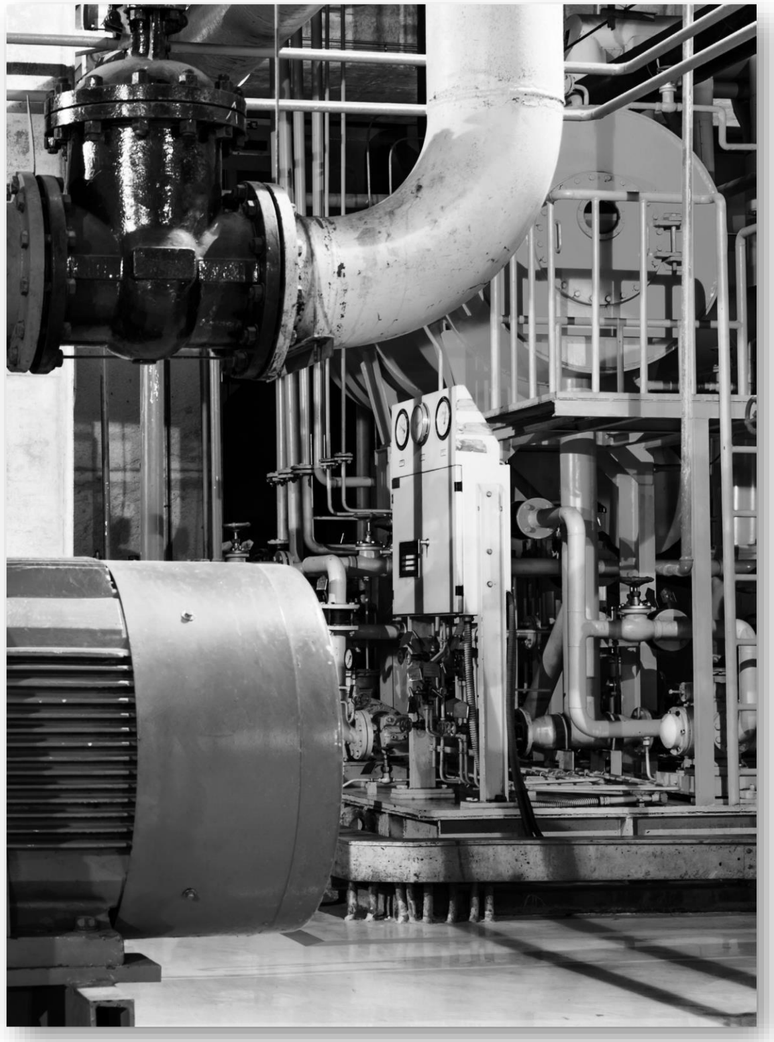
China M100 Trucks

Increased activity commercializing M100 HD trucks underway. 300 HD trucks on road with 500 sales, the total number of could reach around 1000 by the end of 2022. This is delayed due to the global auto-chip shortage, development of the new 13L engine and deployment of M100 filling stations

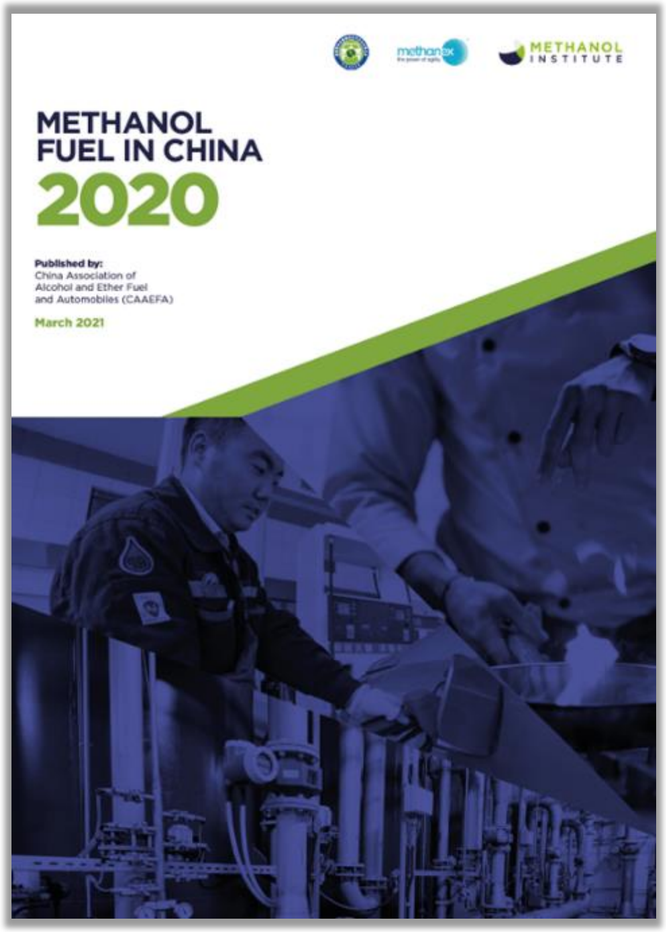
In June, Geely announced first methanol HD rolling off the production line in its Jin Zhong base. The methanol HD truck is 2nd generation with newly developed 13L methanol HD engine. The tandem truck powered by methanol demonstrated in 2021.

In August, Geely announced its new energy truck target with methanol HD truck to achieve 50k units by 2026; as well as the latest model of its HD truck under development, Farizon, is expected to be an EV HD truck with methanol rage extension for total range over 1,000 km, small market sale will be offered by the end of 2023.

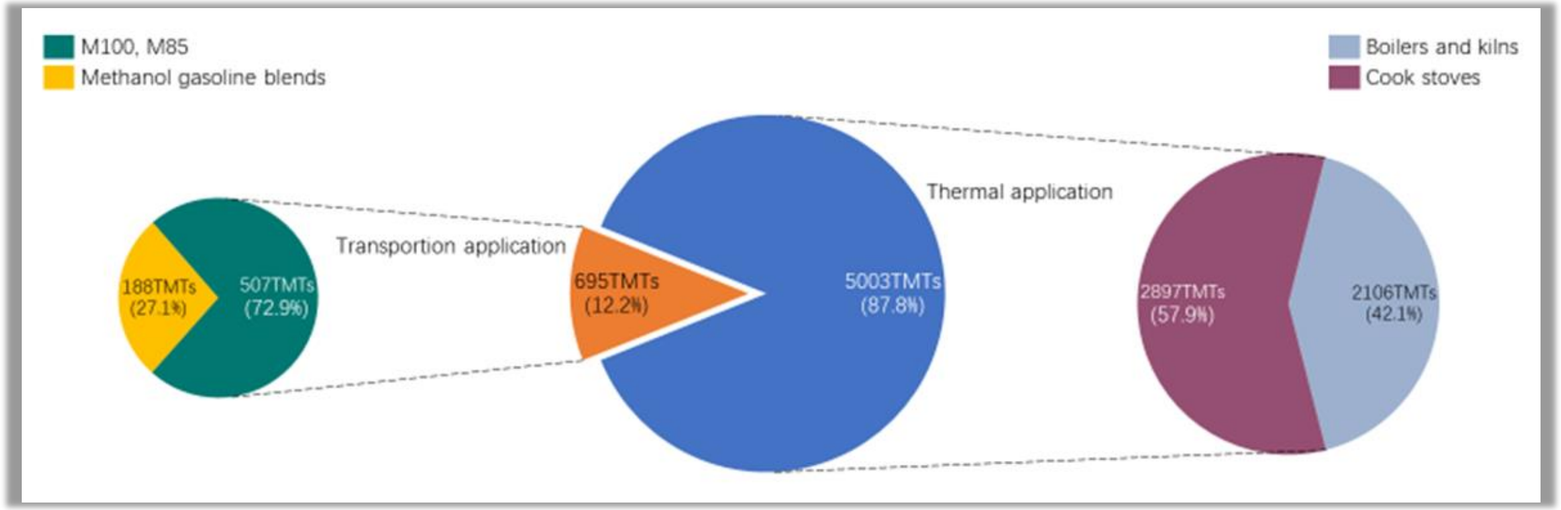
Heat and Power



Methanol Fuel in China



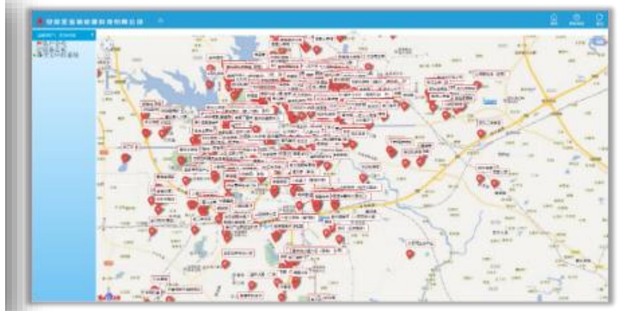
https://www.methanol.org/heat/



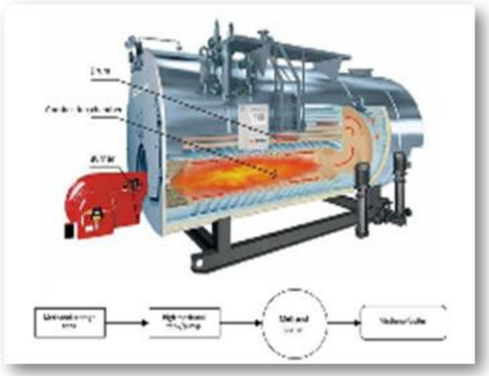
- MI released survey report in 2020 on Methanol Fuel in China
  - 77 companies completes questionnaire
  - 300 companies participated in phone interviews
  - Dozens of site visits
- Close to 6 MMT of methanol fuel found in the survey
- Transportation fuel includes methanol vehicle fuel M100, M85 and methanol gasoline blending
- Thermal applications include boilers, kilns, and cook stoves

Cook Stoves and Industrial Boilers

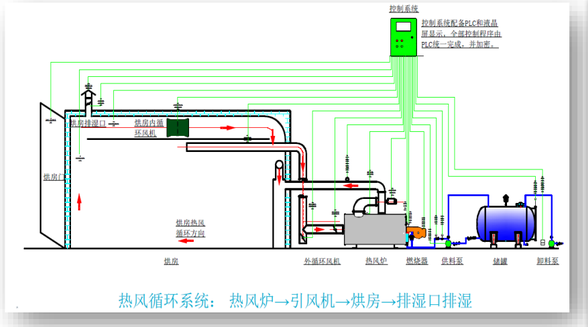
- Different types methanol cook stoves: Single heating, stir fry, steaming
- Widely used in restaurants, central kitchens, mainly cost-driven
- MI and Methanex working with Chinese partners on national cook stove safety standards



- Industrial boilers are widely used for heating and industrial stream
- Many cities in China prohibiting use of coal and diesel fuels
- Capacity ranged from 1 to 20 ton/hour
- One steam ton capacity consumes 110 kg of methanol, and runs 24/7
- Methanol fuel is used neat or as blend with diesel fuel



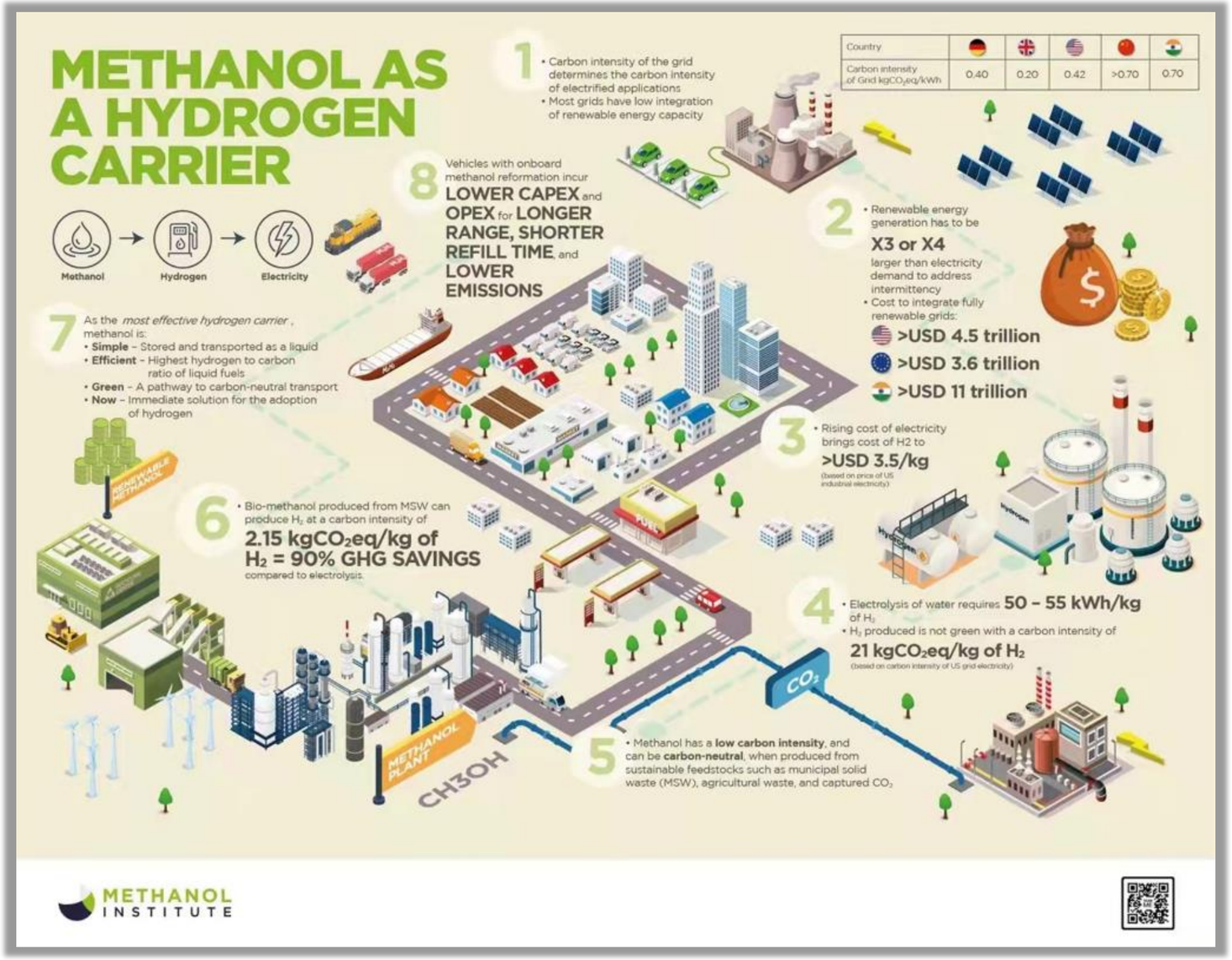
Kilns & Home Heating



- Glass/ceramic kilns – China makes 60% of world's glass products; methanol uses less air intake and produces cleaner flue gas for superior finish

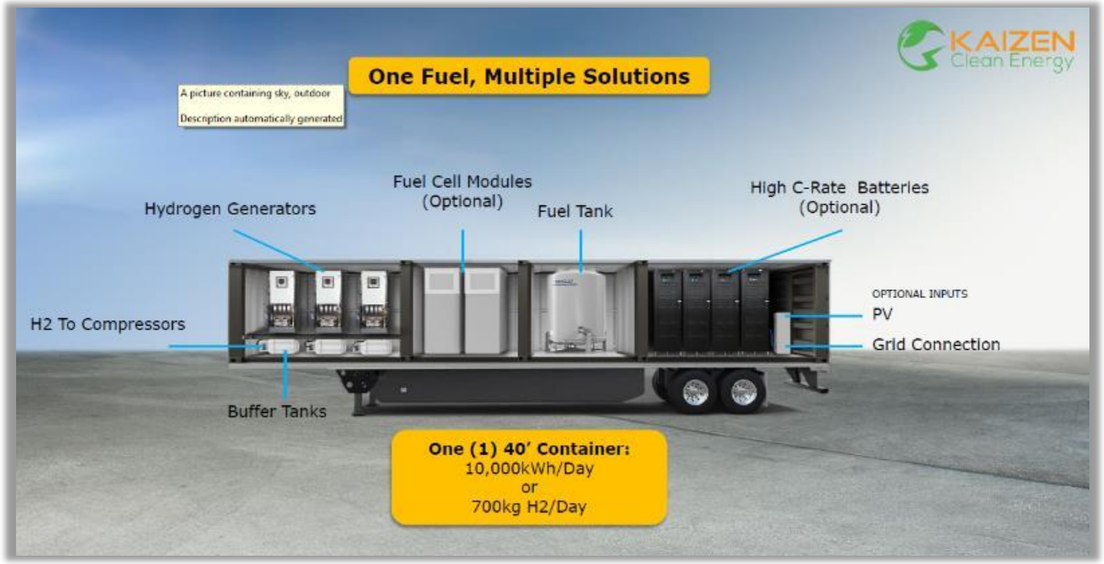
- Beginning in 2018, China using methanol for home heating
- In Shanxi Province, methanol used to heat 50,000 households in 10 counties
- Small heaters for individual families and centralized 2- & 4-ton steam boilers for larger buildings

Hydrogen Carrier Fuel



Practical Solution For FCVs/EVs

- Reformed Methanol Fuels Cells (RMFC) as ***range extender*** for battery electric vehicles
- Increasing range of electric vehicles from 300 to 1000 kilometers
- 3-minute refill with liquid methanol, no charging infrastructure
- Reform methanol at the fueling station to supply hydrogen for fuel cell vehicles and charging for electric vehicles



Fuel Cell Vehicle Canister Rapid Fueling

SMALL, PERSONAL, PASSENGER AND PACKAGE DELIVERY VEHICLES

LOWER POWER REQUIREMENTS = LOWER COST

METAL HYDRIDE AND HYDROGEN “VENDING MACHINES” UNLOCK LOGISTICS & OPERATING COSTS

SunHydro

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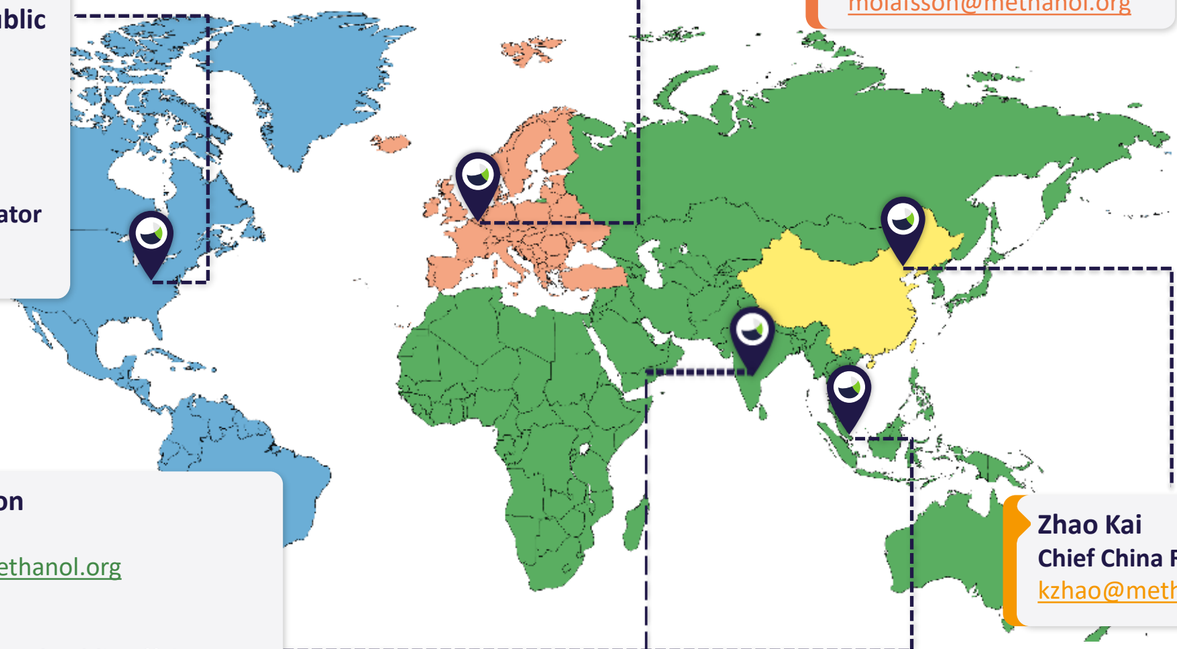

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