ALTERNATIVE FUELS IN DETAIL:
FUELS IN DEMONSTRATION PHASE

GREENVOYAGE 2050

METHANOL

GREENVOYAGE 2050

Overview

- Background and key characteristics
- Methanol fuel production value chain
- Feedstocks and energy sources
- Production technologies
- Onshore requirements
- Onboard requirements
- Regulations, standards and guidance
- Environmental impact
- Cost overview
- Barriers and risks
- Summary

Background and key characteristics

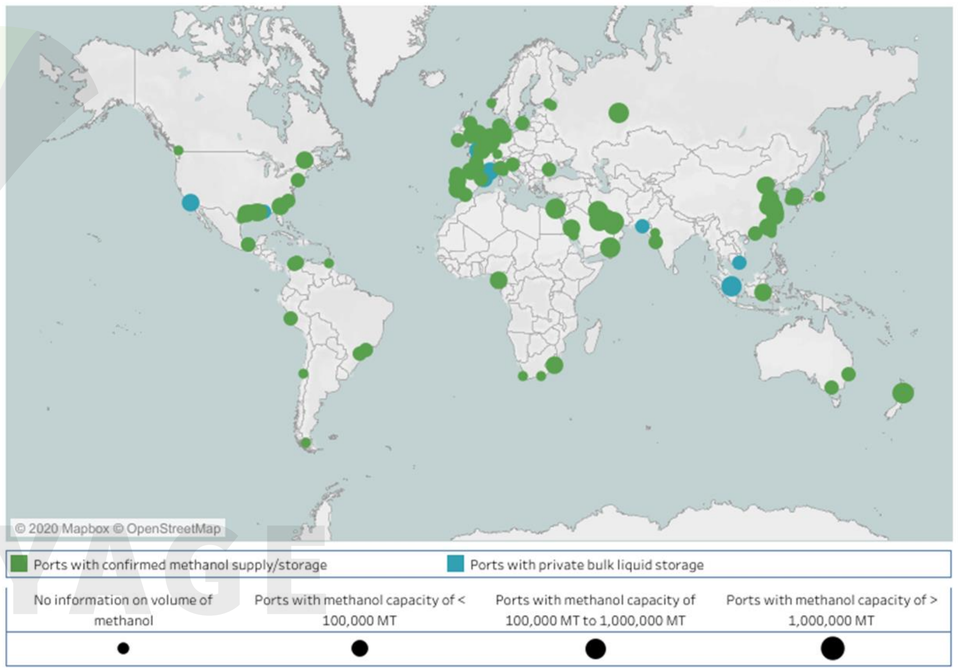
HFO

- Energy density: 42 MJ/kg = 35 MJ/dm^3.
- Flashpoint: 60°C.
- Water solubility: None.
- Most widely-used fuel.

Methanol (CH_3OH)

- Energy density: 20 MJ/kg = 15.9 MJ/dm^3.
- Liquid between –93°C to 65°C at atm pressure.
- Flashpoint: 11°C - 12°C.
- Water soluble.
- Commonly used in industry (e.g. production of chemicals, adhesive products, energy carrier).

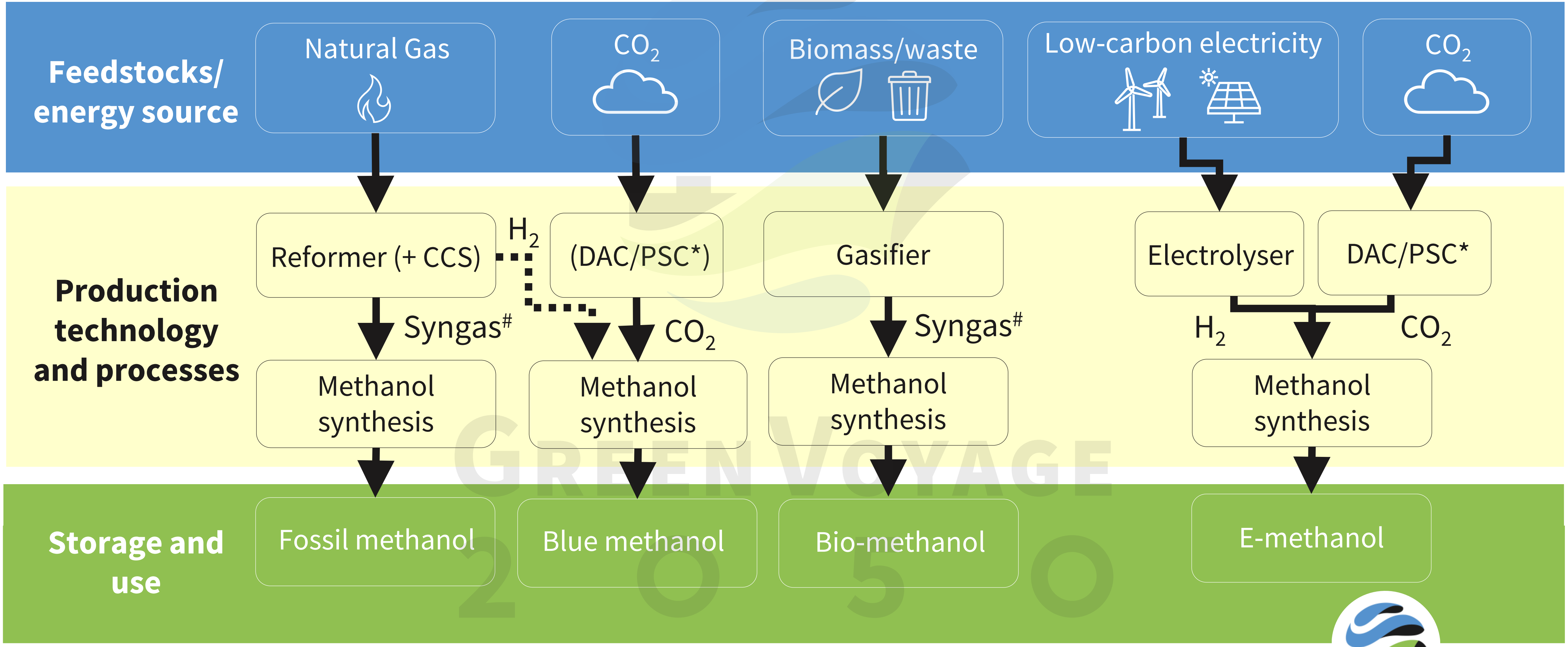
Methanol availability at ports



2019 global supply = 98.3 Million Tonnes[1].

[1]: Methanol Market Services Asia (MMSA).

Methanol fuel production value chains



*DAC = Direct air capture / PSC = Point source capture
#Syngas = mixture of H2/CO/CO2/CH4

Feedstocks and energy sources

Current availability	Natural Gas	Low-Carbon Electricity	CO_2 (DAC)	CO_2 (PSC)	Residual Biomass	Municipal Waste

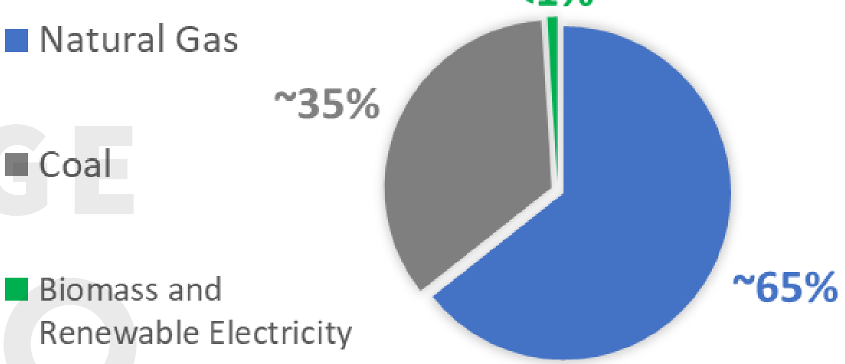
DAC = Direct air capture / PSC = Point source capture

Widely Available | Availability Constrained | Availability Very Restricted

Key Points

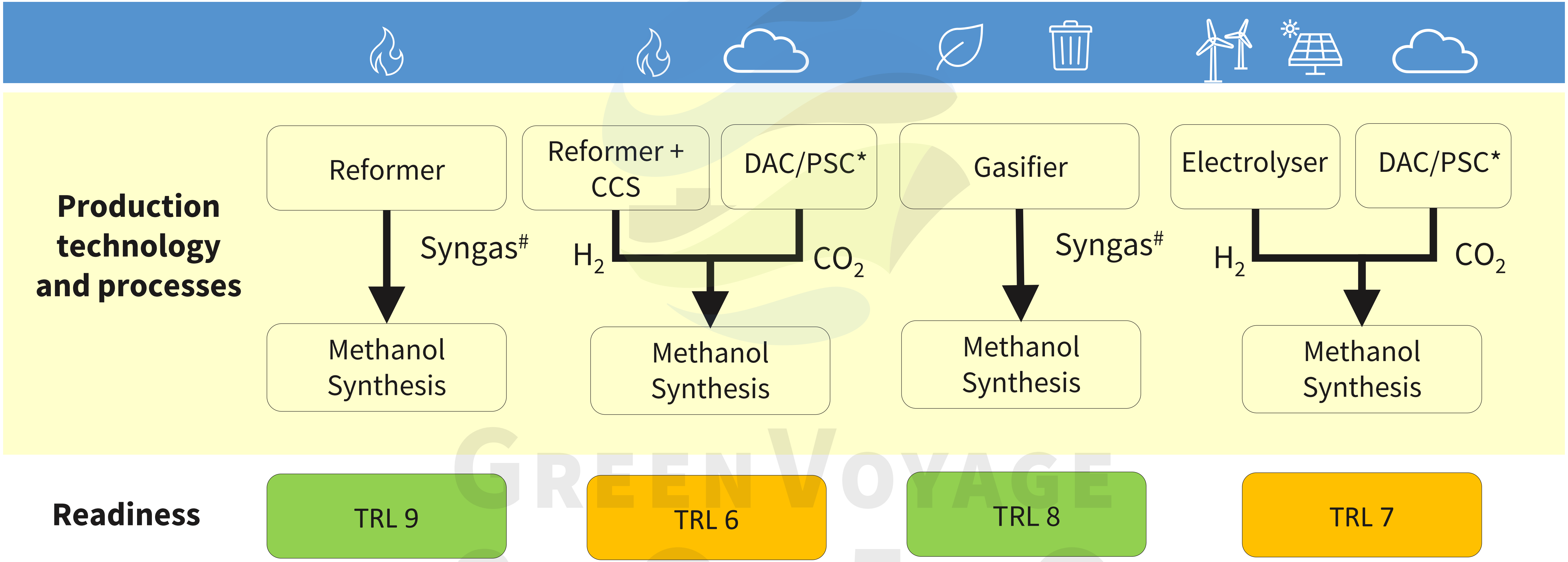
- Nearly all methanol is currently produced using fossil feedstocks (natural gas and coal).
- Alternative feedstocks currently have supply constraints, but these are expected to reduce over time.
- Choice of low carbon production route is likely to be determined by local availability of energy (and CO_2) e.g. cheap NG plus CCS, renewable power or sustainable biomass.

Global Methanol Production by Feedstock



Source: Methanol Institute.

Production technologies



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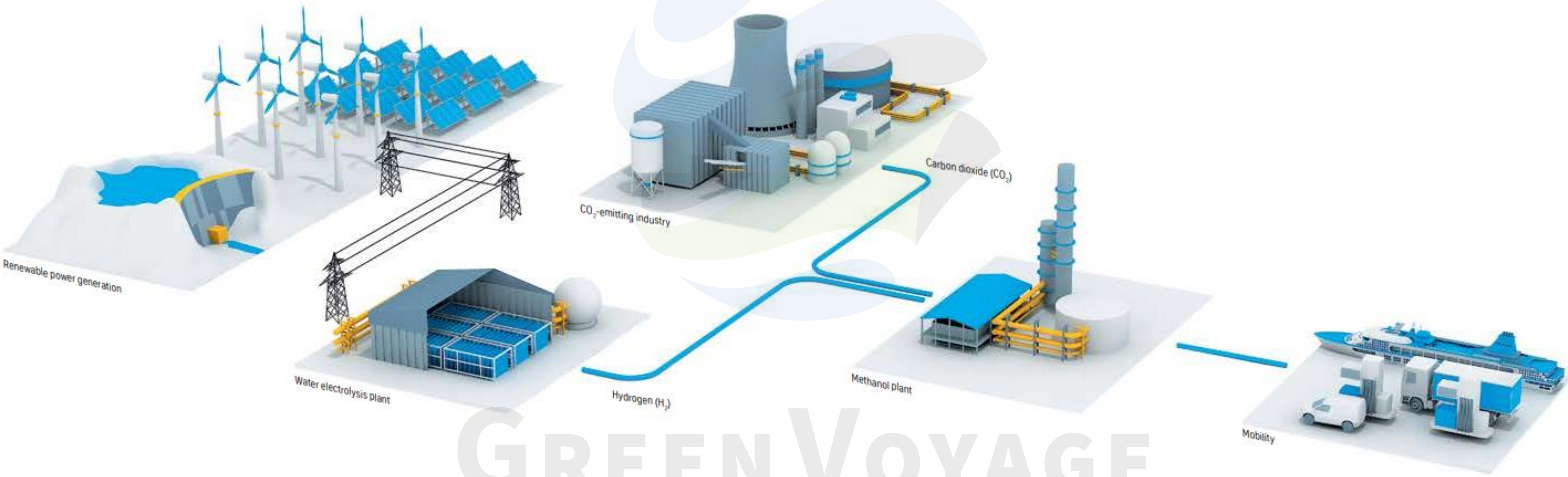
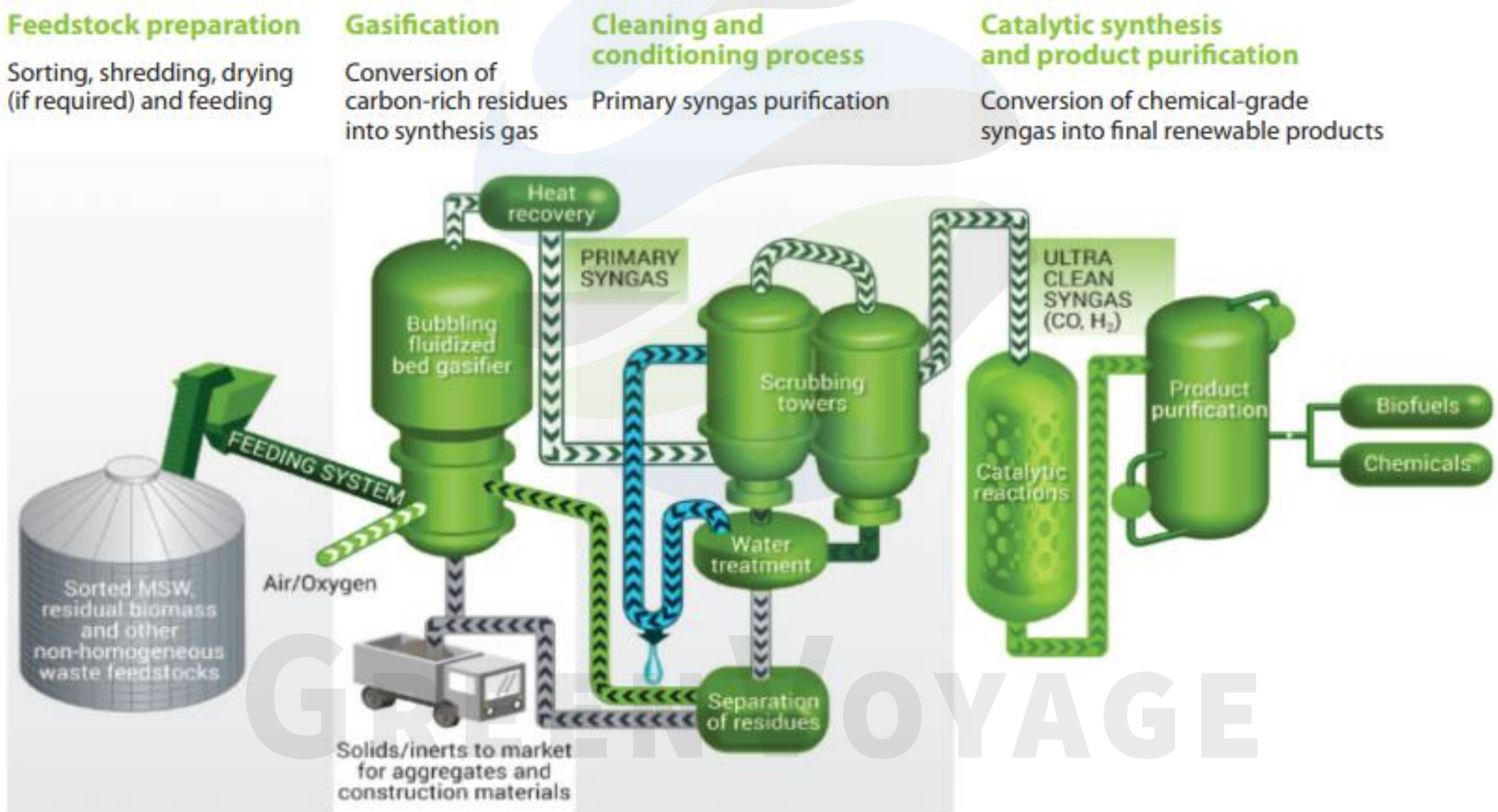
Production technologies



E-methanol production infrastructure, Thyssenkrupp

Source: Thyssenkrupp methanol plants brochure.

Production technologies



Bio-methanol production, Enerkem

Source: Enerkem, via Methanol Institute Renewable Methanol Report, 2018.

Onshore requirements

Storage and use | Methanol

Storage

- Existing storage infrastructure widespread – many ports already have existing methanol storage facilities.
- Only minor modifications are needed to current fuel storage equipment (due to low flashpoint).
- No impact of methanol on stainless steel, ferrous metals or cast iron.

Transportation

- Methanol currently widely transported globally (via ship, trucks and rail).
- Widespread familiarity with loading and unloading methanol as a bulk product.

Onshore requirements

Storage and use

Methanol

Bunkering

- Ship-to-ship bunkering can be carried out with same barge types as HFO/MGO.
- Very few current examples of methanol bunkering due to low level of use as fuel.
- European standard for methanol bunkering approved in June 2020.
- Cost estimates[1]: small bunkering unit installation = 480k USD; bunkering vessel conversion = 1.8m USD.

[1] Methanol Institute: Methanol as a Marine Fuel Report, 2015.

Onboard requirements

Storage

- Double walled pipes required as a low flash point fuel.
- Tanks must be **approximately 2.3x larger** for equivalent energy content of fossil fuels (due to lower volumetric energy density).
- The low viscosity of methanol compared to traditional fuels means that fuel storage and supply systems must be well sealed and maintained to avoid leaks.

Handling

- Methanol is already handled as a cargo product in compliance with Annex II of the MARPOL Convention.
- Regulations covering methanol as a fuel are in draft form and yet to be adopted.

Storage and use | Methanol

Onboard requirements

Propulsion

- Methanol combustion engines already commercially available (including as dual-fuel model).
- Retrofit ICE conversions are possible, adaptations include modifying the fuel injection system.
- Purging system required (N_2 or other inert gas) to enable safe maintenance.
- Use in solid oxide fuel cell (<60% efficient).
- Direct methanol fuel cells under development but low 20% electrical efficiency.

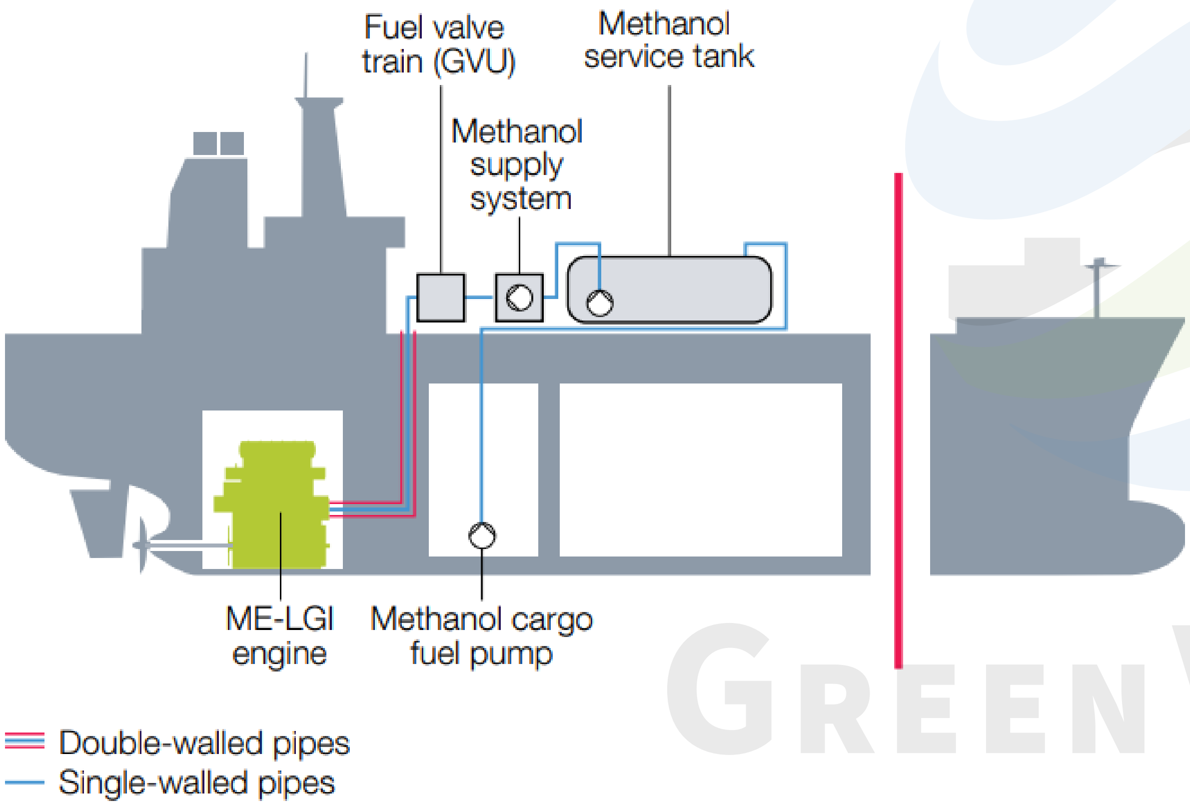
Storage and use Methanol

Methanol propulsion options

Option	Existing fossil engine retrofit conversion	Methanol-ready combustion engine	Fuel cell (e.g. direct methanol/solid oxide)
Readiness	TRL 9 (current examples in service)	TRL 9 (now commercially available)	TRL 6-7 (some operational examples but limited applications)
Capital cost (including required changes to ancillary onboard systems e.g. fuel supply)	Highly project specific. Estimated ~420 USD/kW[1]	Estimated ~320 USD/kW[2]	Highly project specific
Efficiency (at shaft)	<55% (project specific)	55%	<60%

[1] Methanol Institute: Methanol as a Marine Fuel Report, 2015 – based on Stena Germanica retrofit conversion cost. Note value is uncertain for larger engine sizes.
[2] Methanol Institute : Methanol as a Marine Fuel Report, 2015 – reported estimates from MAN based on new-build methanol engine projects.

Methanol engines



Methanol Fuel System Configuration, MAN

Source: Enerkem, via Methanol Institute Renewable Methanol Report, 2018.

ME-LGI two-stroke dual-fuel engine

- Can run on methanol, HFO, MDO, MGO.
- Currently powering seven 50,000 tonne deadweight vessels, launched in 2016.

MAN B&W ME-LGI Engine and Fuel Supply System

Regulations, standards and guidance

Body/Organisation	Documentation	Status/Comment
IMO	Interim Guidelines for the Safety of Ships using Methyl/Ethyl Alcohol as Fuel	Draft, not yet adopted
ISO	Methanol Marine Fuel Grade Specification	Under development
European Committee for Standardisation (CEN)	CWA 17540:2020 Ships and Marine Technology – Specification for Bunkering of Methanol Fueled Vessels	Workshop agreement, not yet official standard
Methanol Institute	Technical Bulletin: Methanol Safe Handling and Safe Berthing	Currently available
Fuel Suppliers	Proprietary guidance	Currently available

Examples of methanol vessels and related infrastructure

Vessels

As of July 2020, 11 ships are operating with methanol as a fuel and another nine other ships are currently being built.

- MS Mariella (passenger ferry) has a methanol fuel cell system - operated by Viking Line between Helsinki and Stockholm since 2016.
- MS Innogy (inland ferry) has a 35kW methanol fuel cell system – operating in Germany since 2017.
- Other current fuel cell projects with methanol as a fuel: Viking Lady (SOFC), E4Ships, RiverCell (HT-PEM).
- Stena Germanica (ferry) is the first commercial ship in the world to run on methanol as its main fuel. Operating from Gothenburg, Sweden.

MS Innogy, Fuel Cell Passenger Ferry

Source: Netherlands Maritime Land and Ministry of Economic Affairs, Methanol as an alternative fuel for vessels report.

Examples of methanol vessels and related infrastructure

Stena Germanica methanol bunkering, Gothenburg

Source: Methanol Institute Methanol as a Marine Fuel Report (handout).

Bunkering and infrastructure

- The MS Innogy project in Germany led to the development of the first methanol infrastructure chain, from production using renewable energy to trucking and ship bunkering to the onboard fuel cell.
- In Gothenburg port, Stena Lines created a dedicated area for bunkering the vessel Stena Germanica which was the first example of a ship bunkering methanol.
- Antwerp Port authority plans to shift from oil derived bunkers to methanol bunkers for its in-port vessels. Three vessels there are set to be capable of using methanol, an inland harbour tug, a pilot boat and a coastguard vessel.

Environmental impacts

	Blue methanol	Bio-methanol	E-methanol	Fossil methanol
Emission reduction drivers	• CH_4 production and transport emissions • CCS efficiency	• Nature of feedstock (e.g. farmed/waste)	• Electricity carbon intensity	
Reduction in well-to-wake GHG emissions*	**42% to 60%[1]**	**85% to 91%[2]**	**58% to 94%[1]**	**Could increase WtW GHGs**

*vs RED II Comparator

Case study

Stena Line, methanol ferry conversion

Emission reductions

SOx	PM	NOx
-99%	-95%	-60%

Source: Stena Lines

Fuel cost overview

Production route	Blue methanol	Bio-methanol	E-methanol	Fossil methanol
Key drivers (Expected trend: positive/negative/either)	• Natural gas price • CCS CapEx	• Feedstock cost • Conversion cost	• Green power cost • Electrolyser CapEx and utilisation	
Current production cost (per GJ fuel)	**21 – 237 USD**	**22 – 35 USD**	**58 – 463 USD**	**Current methanol market price vs HFO market price**
Current production cost vs HFO market price (per GJ fuel)	Additional 8 – 231 USD[2]	Additional 9 – 28 USD[2]	Additional 46 – 456 USD[2]	-1 to +19 USD
Potential for cost reduction vs current cost	High for CCS	Medium	High	

Figures quoted based on available data as of Dec 2020.

Source: E4tech analysis – Sub-Group on Advanced Biofuels Sustainable Transport Forum (2017), Building up the future.
[1]: Feedstock = Forestry residue; yield: JEC Well-to-Tank (2014). Note cost could be lower if municipal solid waste is used.
[2] based on HFO market price of 250 – 500 USD/tonne.

Barriers and risks

Category	Barrier / Risk	Rating
Policy	Lack of certainty on future government and inter-government support for methanol compared to other alternative fuels.	High – ongoing uncertainty can lead to inaction within fuel supply industries.
Commercial	High production costs.	High – high fuel cost is a strong barrier to widespread adoption. However, significant cost reductions are expected across production pathways and policy action may make economics more favourable.
	Cost of engine replacement/conversion.	Medium – increasing commercial offering of methanol engines.
	Low volumetric energy density leads to loss of space for cargo or passengers.	Medium – (application specific).
Sustainability	Potential for sustainability concerns from some biomass/waste sources.	High – feedstock specific

Methanol summary

Key points

- Methanol is currently widely handled as a cargo with recognised regulations and guidelines.
- There has been very limited deployment as a marine fuel to-date, but promising results achieved by early adopters.
- Production routes use generally well understood processes, but there are some feedstock constraints.
- Engine retrofit conversion possible, but availability of 'off-the-shelf' methanol engines is also increasing.
- Onshore infrastructure and equipment for storage and transportation of methanol is well understood in principle.
- It is liquid at atmospheric pressure and temperature, making it relatively easier to store onshore and onboard
- Cost comparisons show that while currently more expensive that MGO and HFO, there is potential for future cost reductions.
- All low carbon routes have components at an early stage of commercialisation: CCS for fossil routes, gasification for bio/waste routes and combined renewable electricity, fuel synthesis and ultimately DAC for e-fuel routes.
- While the use of methanol shows promising technical readiness in several areas, progress towards a position of widespread adoption would still be hampered by several commercial, policy and sustainability barriers, as well as the starting point of very limited current use.