Evaluation of green methanol versus ammonia as future marine fuel

Hydrogen & P2X

2024

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Agenda

Ammonia as new marine fuel?

1. Fuel cost
2. Decarbonization potential
3. Safety and risk assessment

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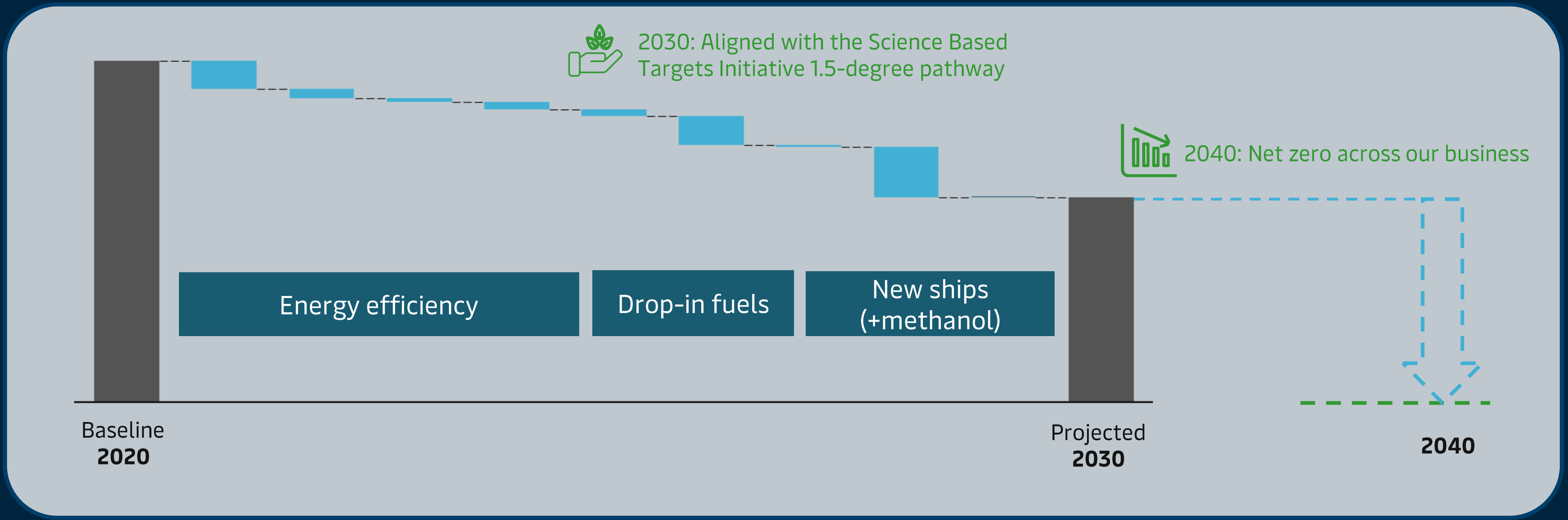
Decarbonization levers and commitments



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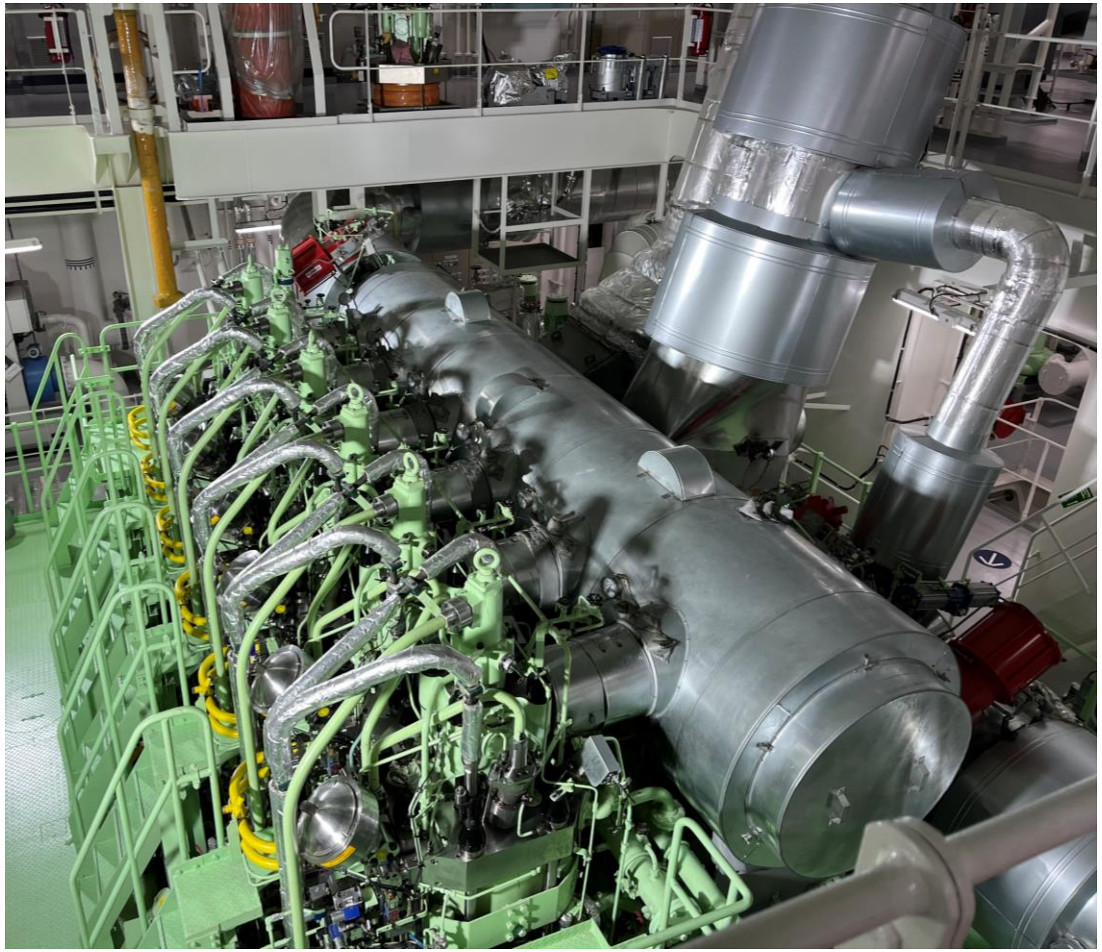
The chicken has finally met the egg

Maritime decarbonization by green methanol



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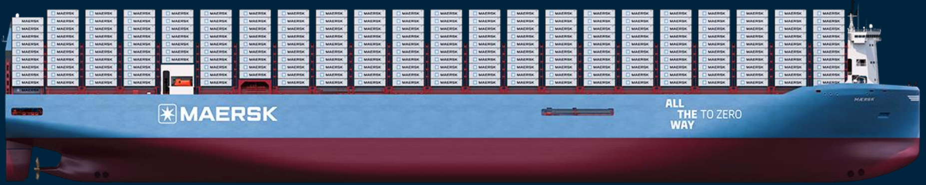
New Maersk methanol ships

Laura Maersk: 2,100 TEU, ~15,000 ton methanol per year

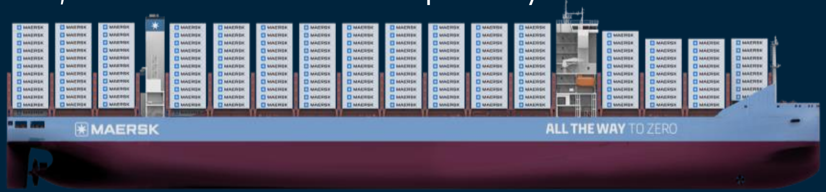
Morten Bo Christiansen: The first-ever cargo ship powered by green fuel | TED Talk

2,100 container capacity — 1

16,000 - 17,000 container capacity — 18



9,000 container capacity — 6



Milestone: Maersk launches methanol-powered feeder in bold move toward carbon neutrality - Offshore Energy (offshore-energy.biz)

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Building a supply chain for green methanol

Kassø Denmark

Renewable power:	New 300 MW Solar PV
Green hydrogen:	50 MW electrolyzers
Biogenic CO_2:	From nearby biogas facility
Product:	30 kton of E-methanol per year

Breaking ground, May 2023

European Energy breaks ground on grand e-methanol facility (energywatch.com)

EUROPEAN ENERGY

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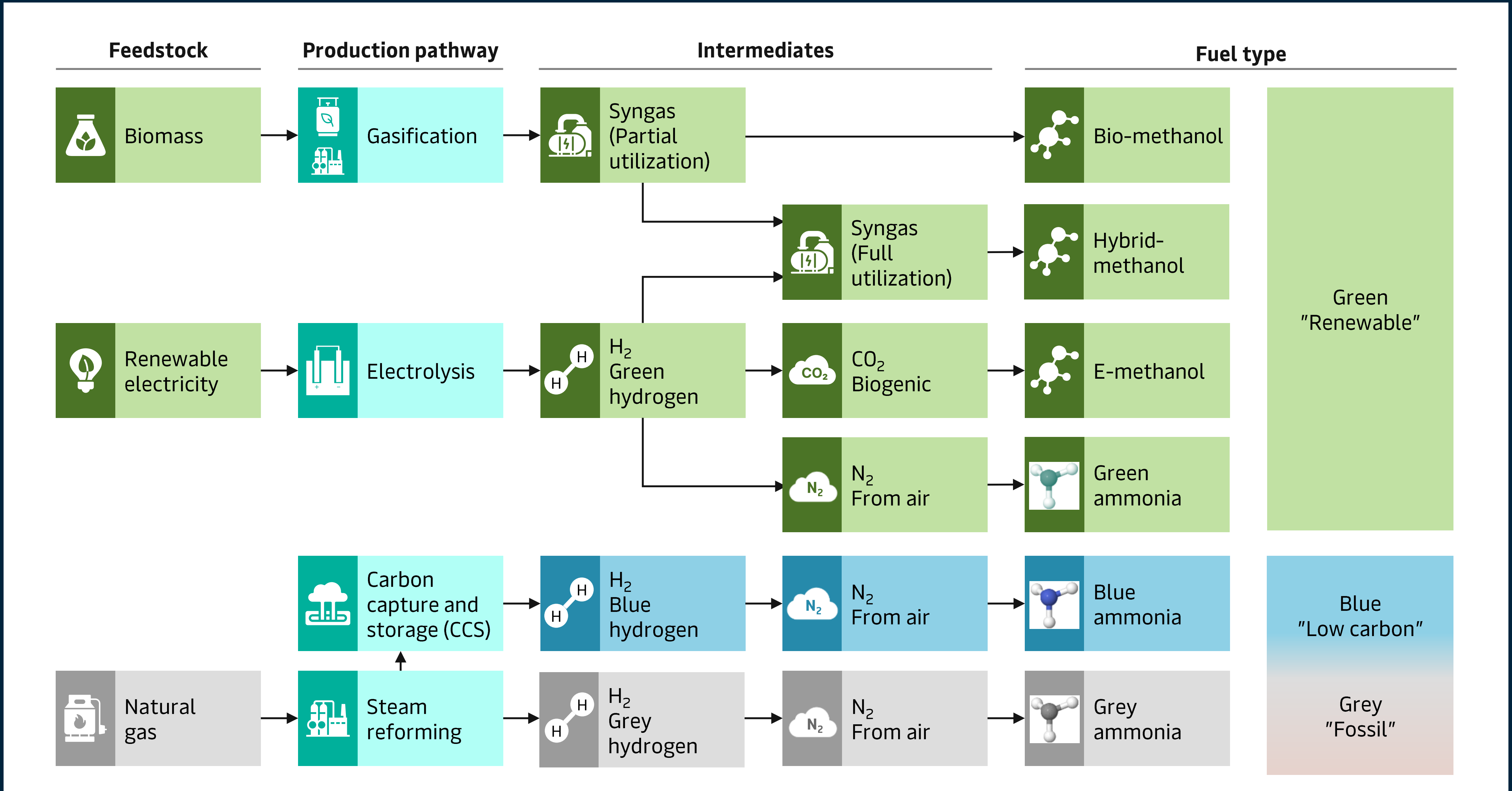
Complex production landscape



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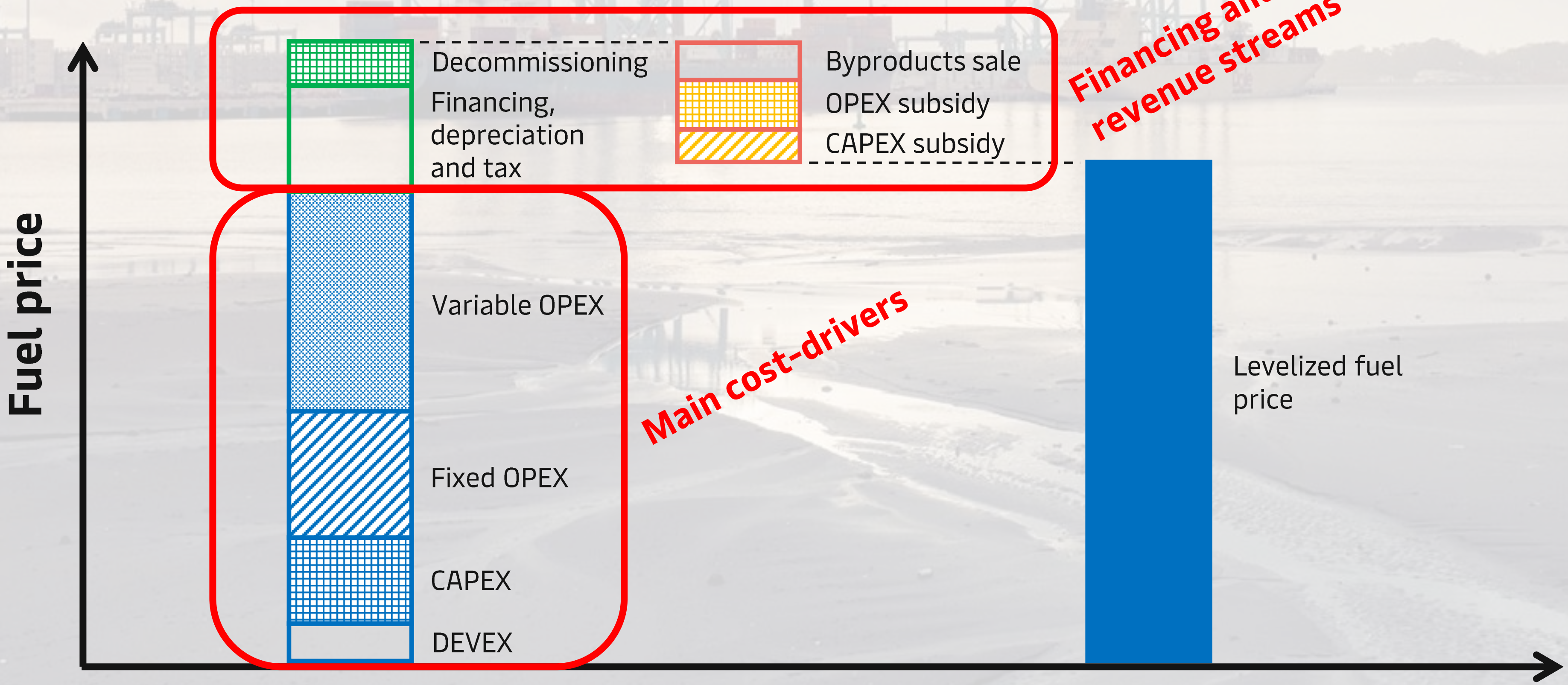
Fuel costs

Techno-economic **modeling**

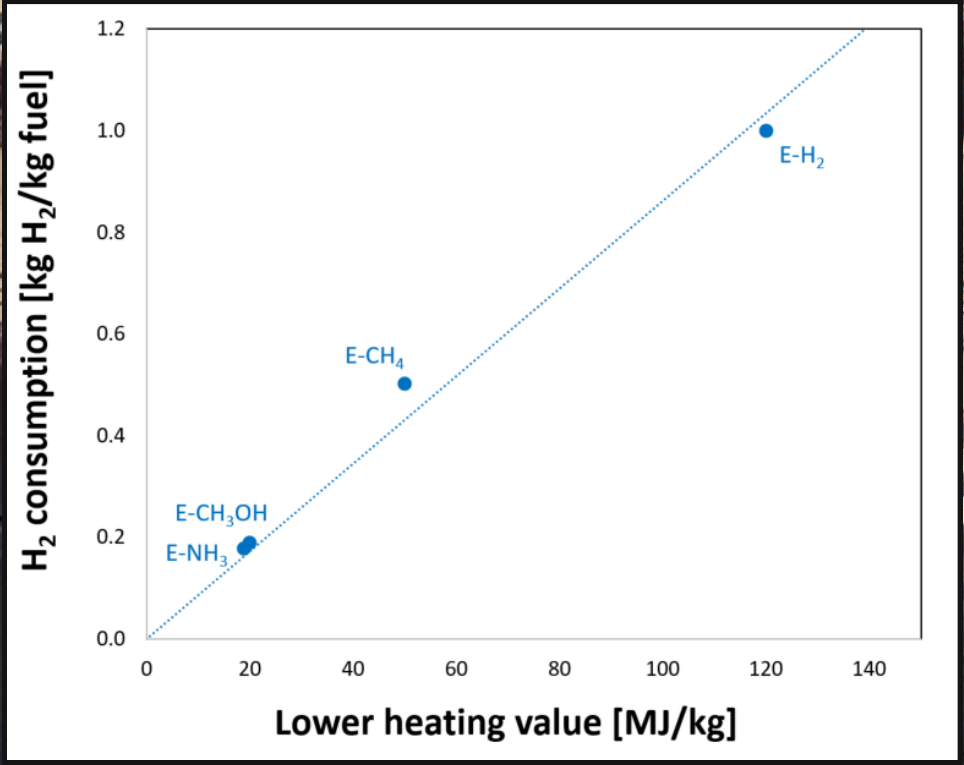
LCOM: The LCOM is the average revenue per unit of methanol generated that is required to recover the costs of building and operating a plant during an assumed financial life, i.e. as seen from a 'total-cost-of-ownership' (TCO) perspective.

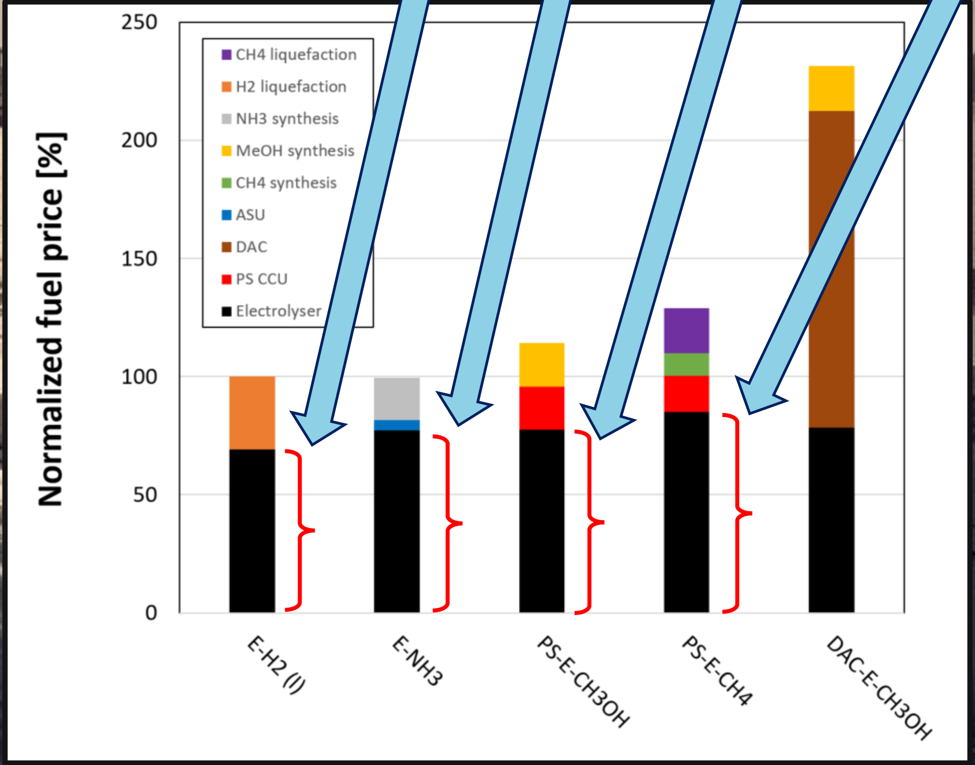


Fuel costs

Green hydrogen consumption

- The relative hydrogen consumption of E-fuels is comparable.
- Electrolyser related fuel costs are comparable, but in the order: E-H_2 < E-NH_3 ≈ E-CH_3OH < E-CH_4

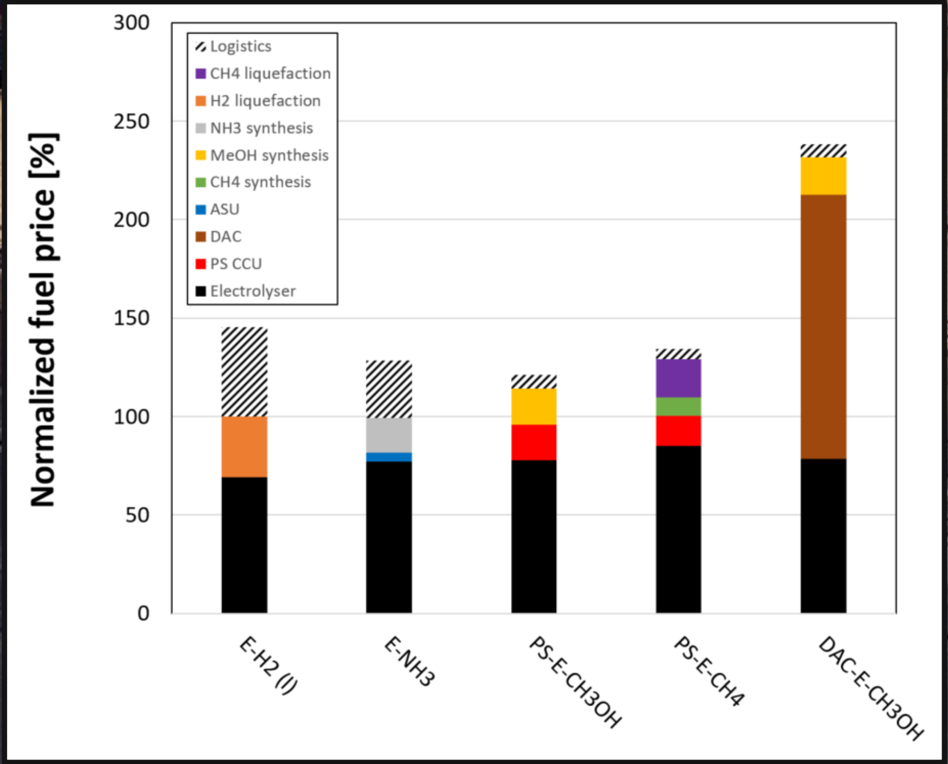




Fuel costs

Logistics costs

- Fuel cost ranking may change if logistics costs are included! → Case specific...
- Hydrogen and ammonia can be expensive fuels to transport, store and bunker.
- Methanol is competitive in this regard.



Assumed transport/storage/bunkering costs

H_2	2000 €/ton	(17 €/GJ)
CH_3OH	50 €/ton	(2.5 €/GJ)
CH_4	100 €/ton	(2.0 €/GJ)
NH_3	200 €/ton	(10.6 €/GJ)

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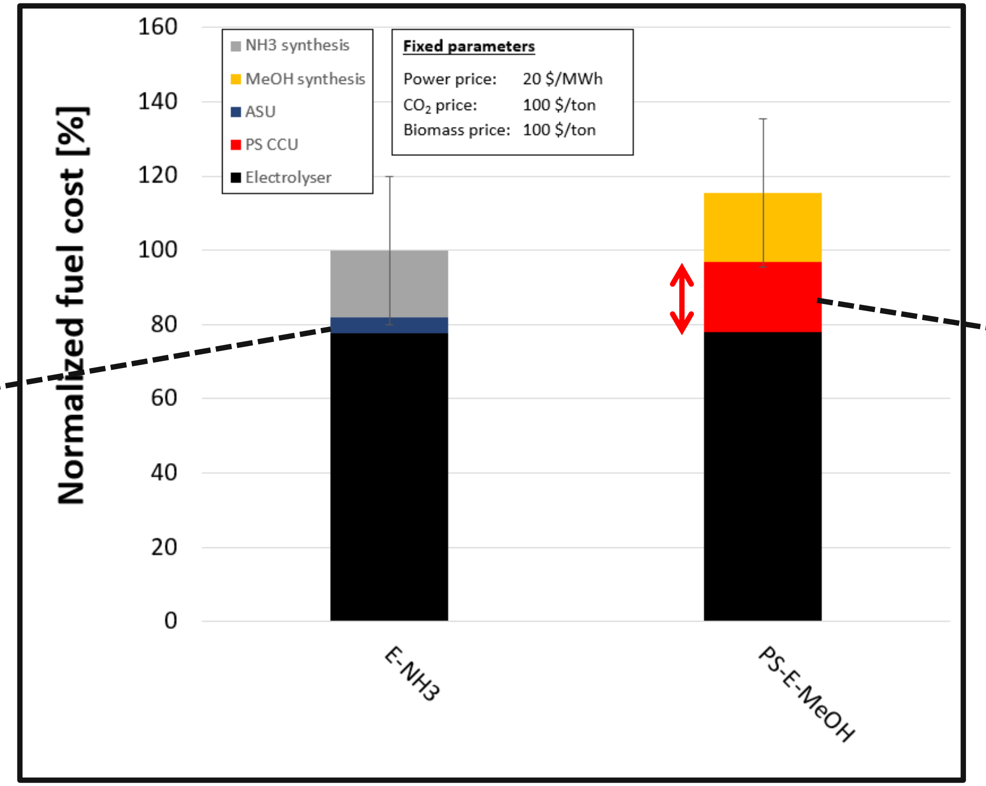
Fuel costs

E-methanol versus E-ammonia

- Based on dilute flue gas capture, production of E-methanol is ~15% more expensive than E-ammonia.
- The difference is mainly based on nitrogen and CO_2 capture costs.
- Nitrogen capture based on air separation is very mature technology and cost effective.
- **But:** CO_2 capture costs can vary among point-sources, e.g. 20-150 $/ton CO_2

Example of cryogenic air separation unit



Example of point-source amine-based CO_2 capture unit

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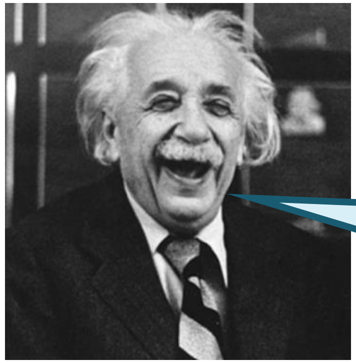
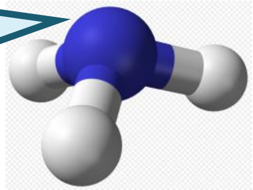
Scalability of methanol and ammonia



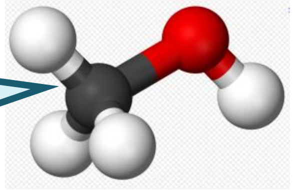
Ammonia is superior to methanol due to carbon independency!

Feedstock sensitivity of E-fuel pathways		
	E-NH_3	E-MeOH
Power	High	High
CO_2	-	High

You will never beat me on the E-pathway…



I am not far behind…



Source: https://www.capturemap.no/

Scalability of E-methanol:

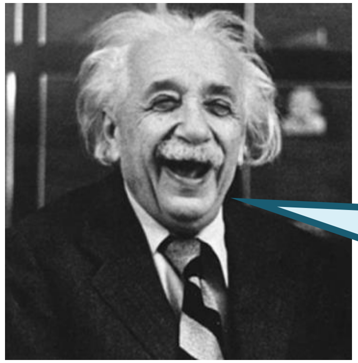
- **Feedstock – Power:** Comparable dependency (0.5-0.7 MWh_e/GJ_{LHV}).
- **Fuel cost:** 0-15% more expensive than E-NH_3 at identical project conditions.
- **Feedstock – CO_2:** Plenty of unused biogenic CO_2 from point-sources.

Point-source	Biogenic CO_2 emissions in Europe and North America [Mtons/year]
Ethanol plants	44
Biomass power plants	53
Waste to energy plants	52
Pulp and paper	181

Source: https://www.capturemap.no/

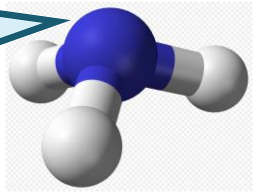
Scalability of methanol and ammonia

Feedstock sensitivity of E- and Bio-fuel pathways				
	E-NH_3	E-MeOH	Bio-MeOH	Hybrid-MeOH
Power	High	High	-	Medium
CO_2	-	High	-	-
Biomass	-	-	High	Medium



People claim…
Ammonia is superior to methanol due to carbon independency!

You will never beat me on the E-pathway…



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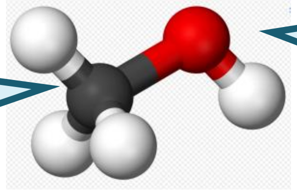
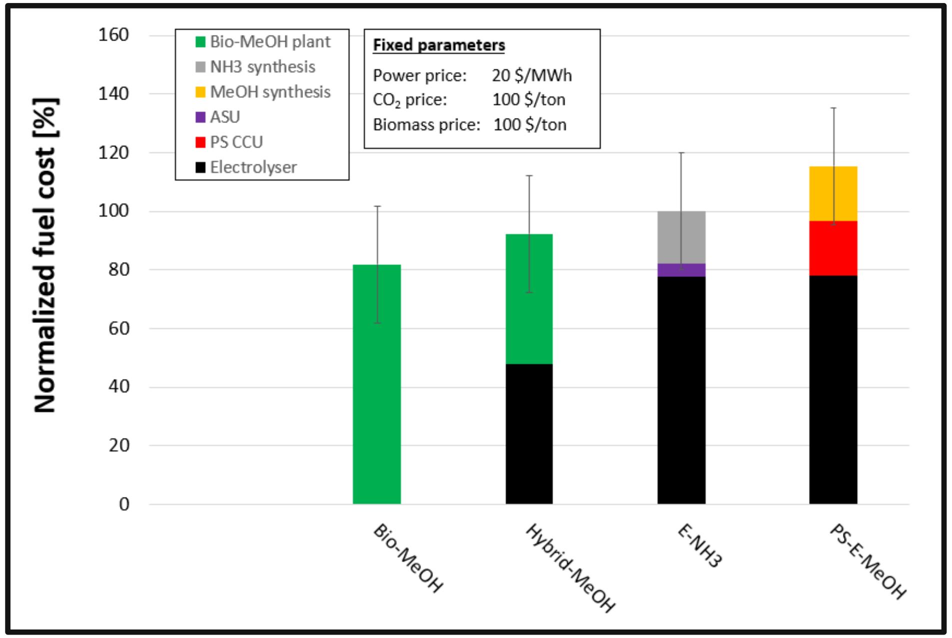


You don't have chance on the Bio-pathway…



Scalability of Bio-methanol:

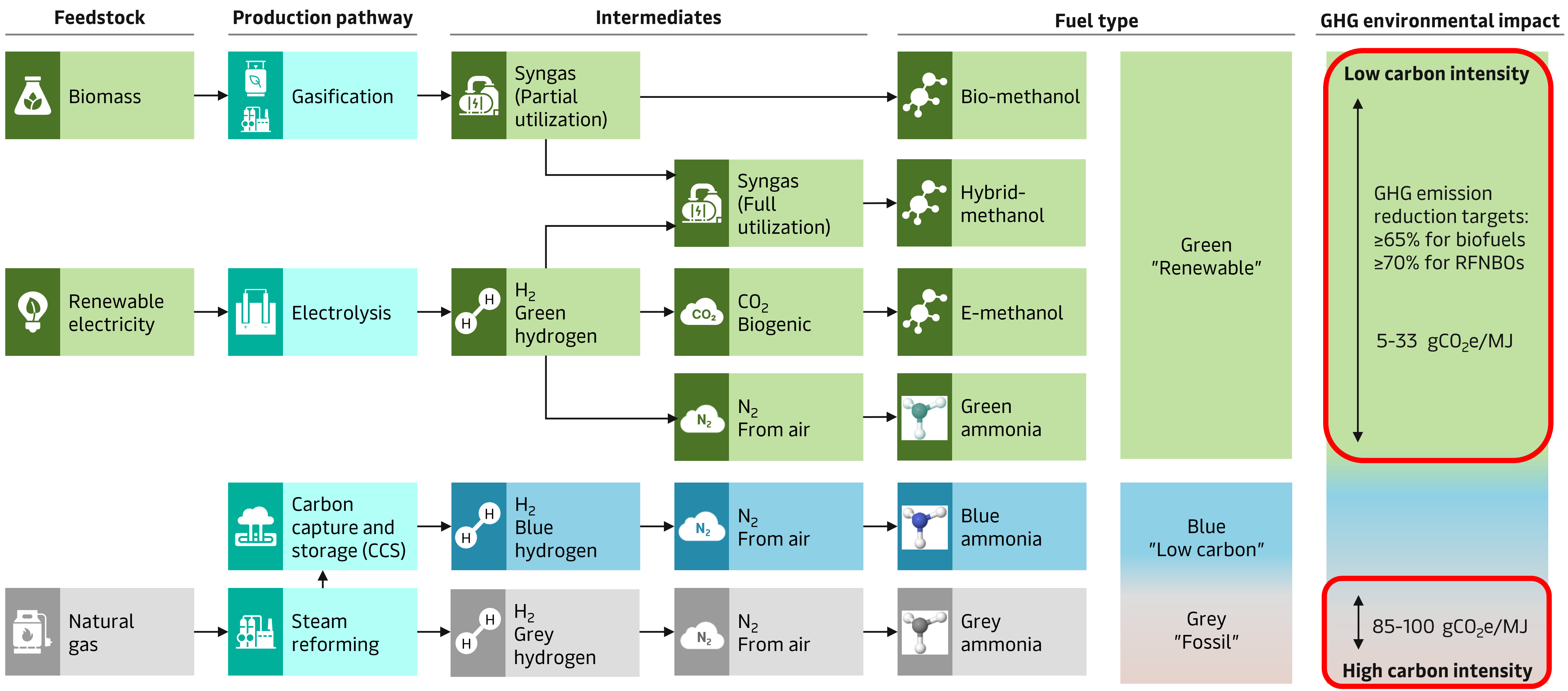
- **Feedstock – Biomass:** Methanol can be produced from sustainable biomass – Ammonia cannot!! Carbon dependency may be an advantage…
- **Flexible production:** Methanol can be produced by a combination of E- and Bio-pathways → Hybrid-methanol.
- **Fuel cost:** Up to ~20% lower than E-ammonia.

Market observations:

- The different pathways of green methanol provide a diverse project portfolio.
- Financially, bio-based green methanol projects are particular competitive.

Decarbonization potential

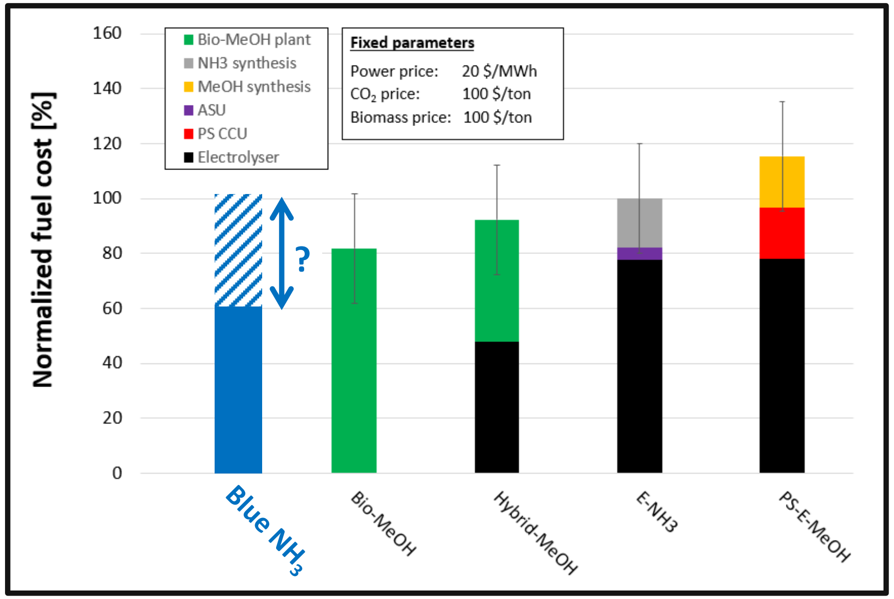
GHG environmental impact

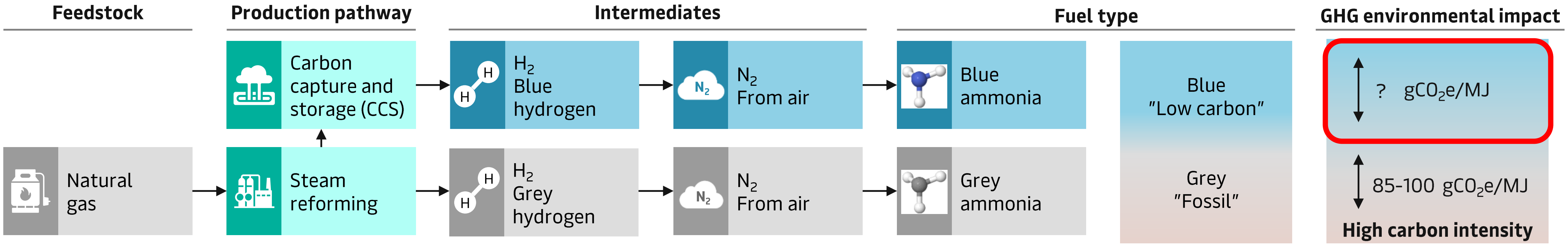


Blue fuels – A joker in the maritime decarbonization

Blue fuels are still a big joker:

- **Fuel cost**
  - Revamp costs of grey plants with CCS investments?
  - Subsidies?
  - Future natural gas prices?
- **Logistics**
  - CO_2 transportation and geological storage availability?
- **Decarbonization potential**
  - Life cycle emissions?
  - Methane slip?
  - Capture efficiency?





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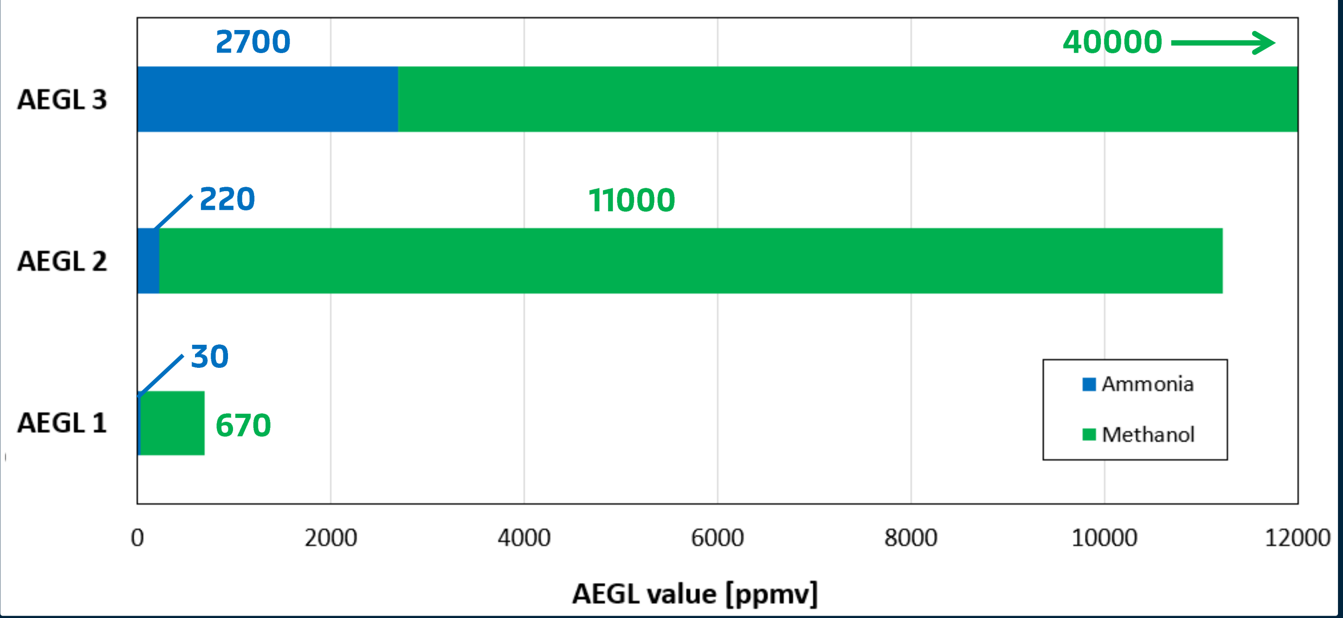
Safety aspects of ammonia versus methanol

Definition: Acute Exposure Guidelines Levels (AEGLs) express specific concentrations of airborne chemicals at which human health effects are expected following accidental releases into air.[1)]

Level	Characteristics
AEGL 1	Discomfort, irritation (reversible)
AEGL 2	Serious adverse health effects (irreversible)
AEGL 3	Life-threatening health effects or death.

AEGL for ammonia and methanol @10 min.



- **Simple toxicity comparison:**
  - **Human health:** Airborne ammonia is ~15 times more toxic than methanol based on AEGL-3 values.
  - **Marine ecological:**
    - Typically, $LC_{50}(NH_3)$ < 1 mg/L (fish)[2)]
    - Typically, $LC_{50}(CH_3OH)$ > 15,000 mg/L (fish)[3)]
- **Consequences:**
  - **Ship design:** Proper design and mitigation measures must be in place to ensure ALARP criteria.
  - **Procedures and training:** Extensive operational procedures and trained personnel are required.
  - **Regulation:** National and international safety regulatory standards must be in place.
  - **Maersk:** Together with external partners, Maersk is involved in extensive safety studies covering HAZID, HAZOP and QRA as well as spill studies to identify human health risks, environmental risks and mitigation requirements.

1) https://www.epa.gov/aegl/
2) https://www.mda.state.mn.us/ecological-effects-ammonia
3) Methanol(67-56-1)_BZ_EN June 2017.pdf (methanex.com)


Thank you!
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