Use of hydrogen for production of E-fuels and biofuels in the maritime sector

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Agenda

- Maersk’s decarbonization strategy
- New marine fuels → Value propositions and challenges
- Fuel costs and techno-economic modeling
- Learnings from feasibility study on fuel cell powered feeder vessel concept

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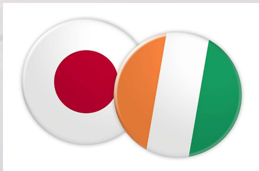
Maersk's decarbonization strategy

The starting point

- The maritime sector consumes **300 million tonnes of fuel oil per year**, and emits **3%** of global GHG emissions.
- Maersk consumes **11 million tonnes of fuel oil per year** and emits **0.1%** of global GHG emissions

Equal to CO_2e emissions of Japan (~1 bn ton) [Global Shipping Emissions: Why Shipping is a Dirty Industry Burning a Dirty Fuel]



Equal to CO_2e emissions of Ireland (~33 mill ton) [Ireland CO2 Emissions - Worldometer (worldometers.info)]

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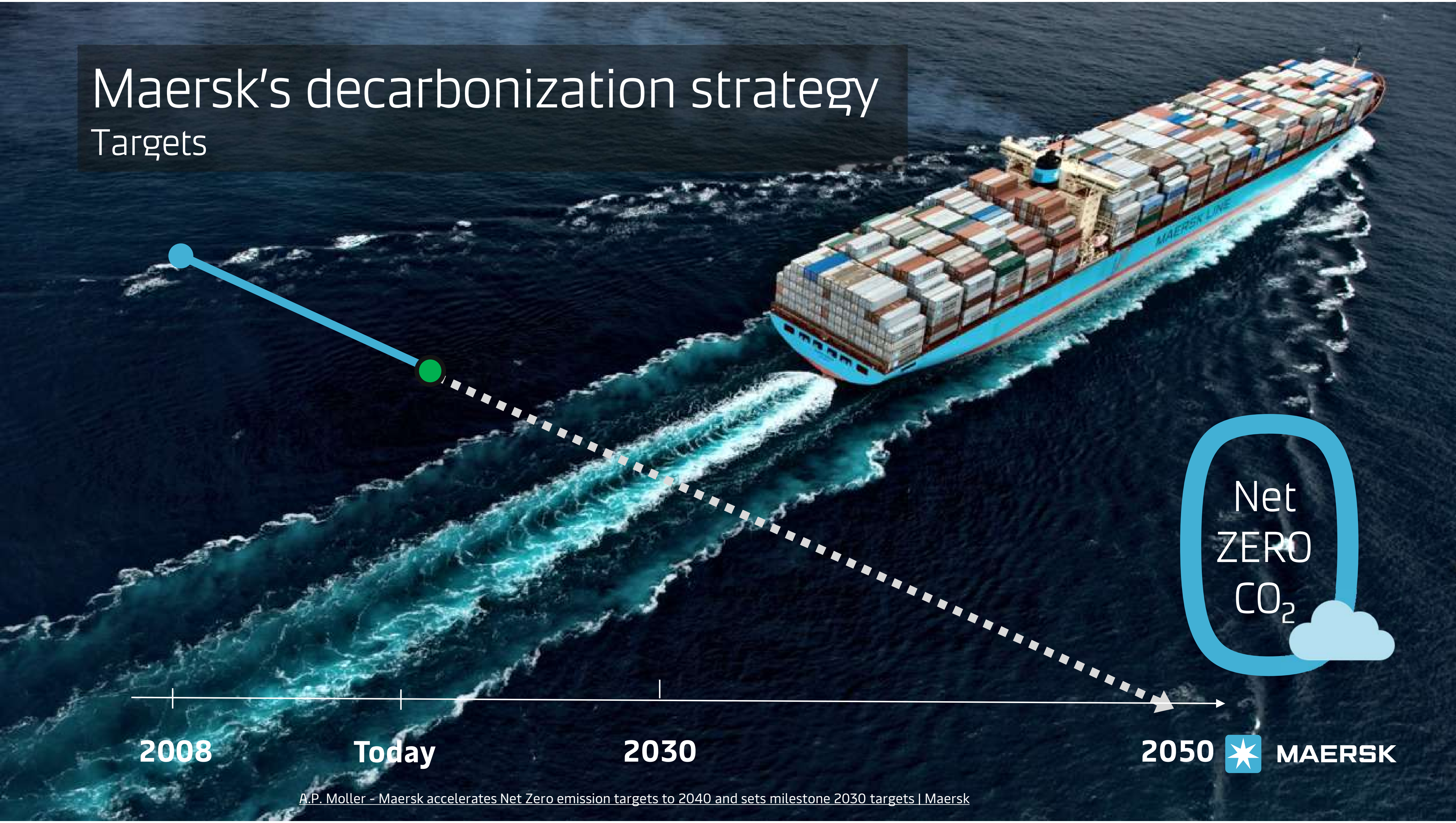
Maersk's decarbonization strategy

Targets



A.P. Moller - Maersk accelerates Net Zero emission targets to 2040 and sets milestone 2030 targets | Maersk

Maersk's decarbonization strategy

Targets

Ships: Future Maersk-owned new-buildings will be prepared to sail on carbon neutral fuels.

Terminals: ~70% absolute reduction of greenhouse gas emissions.

Air: Min. 30% of cargo transported using Sustainable Aviation Fuels.

Warehouses: Min. 90% green operations.

SBTi: Our targets will be aligned with the **1.5°C pathway** as defined by SBTi for the maritime transport sector.

50%
Red. pr container transported (2020 baseline)

35 - 50%
Absolut reductions (depending on growth) – ocean only

Net ZERO CO_2

2008 | Today | 2030 | 2040 | 2050

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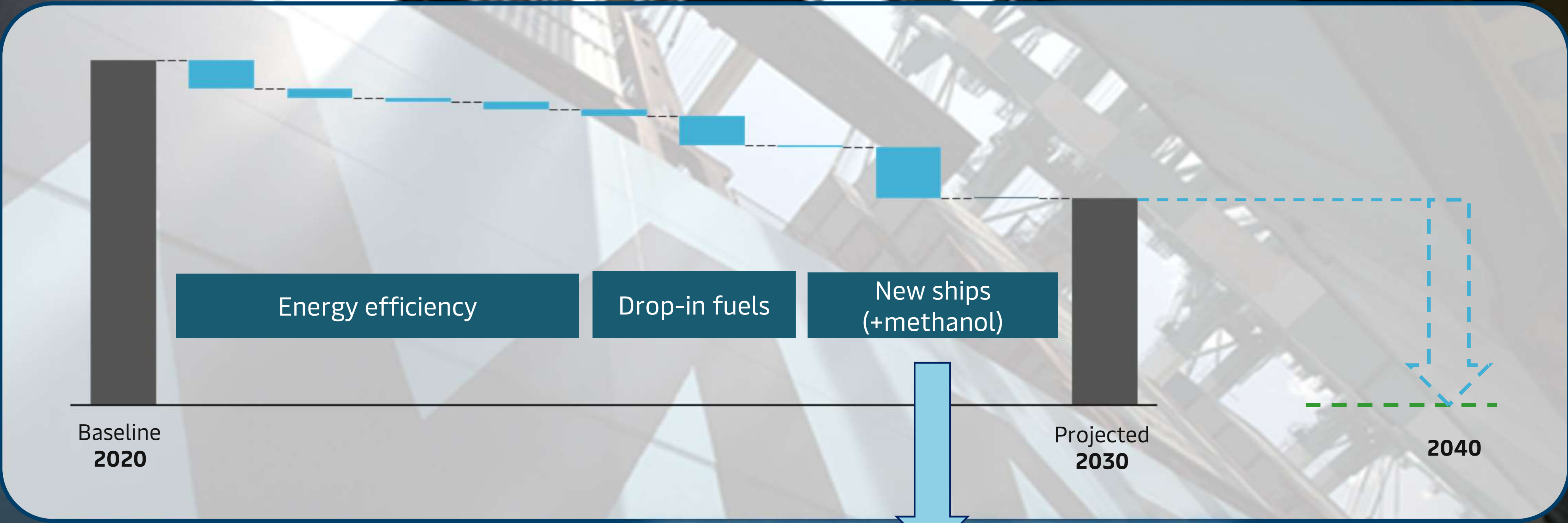
[A.P. Moller - Maersk accelerates Net Zero emission targets to 2040 and sets milestone 2030 targets | Maersk]

Maersk's decarbonization strategy

Decarbonization levers



19 dual fuel ships ordered to date

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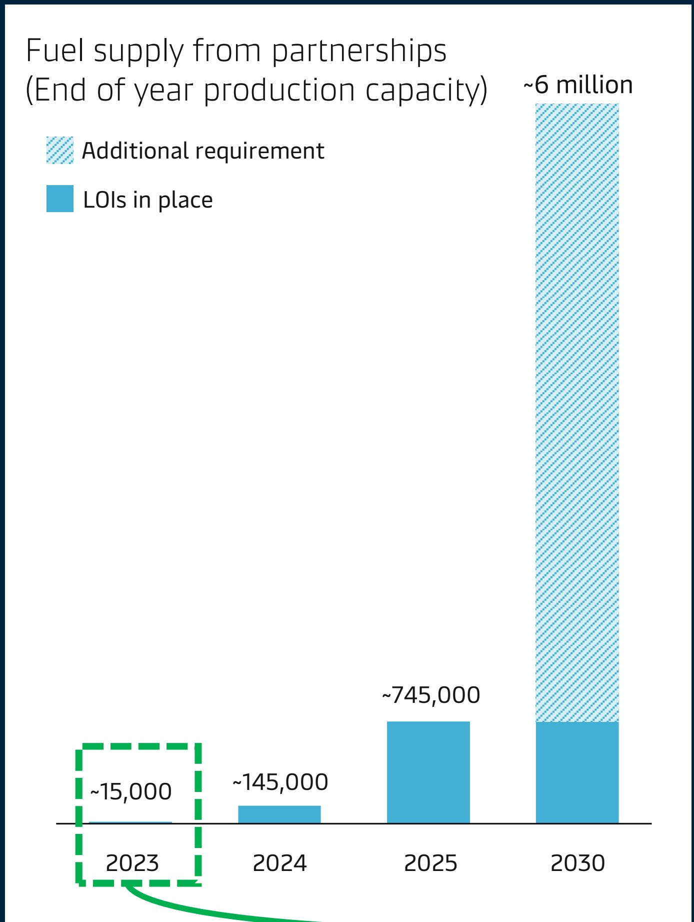
Maersk's decarbonization strategy
New fuel demand



Milestone: Maersk launches methanol-powered feeder in bold move toward carbon neutrality

VESSELS

April 14, 2023, by Jasmina Ovcina Mandra

Container shipping heavyweight Maersk has achieved a major milestone in its efforts to reduce carbon emissions with the successful launching of its first methanol-powered feeder vessel at the Hyundai Mipo Dockyard.

Plus 5-10% biodiesel for 'pilot fuel'!

Classification: Public

A.P. Moller - Maersk continues green transformation with six additional large container vessels | Maersk

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

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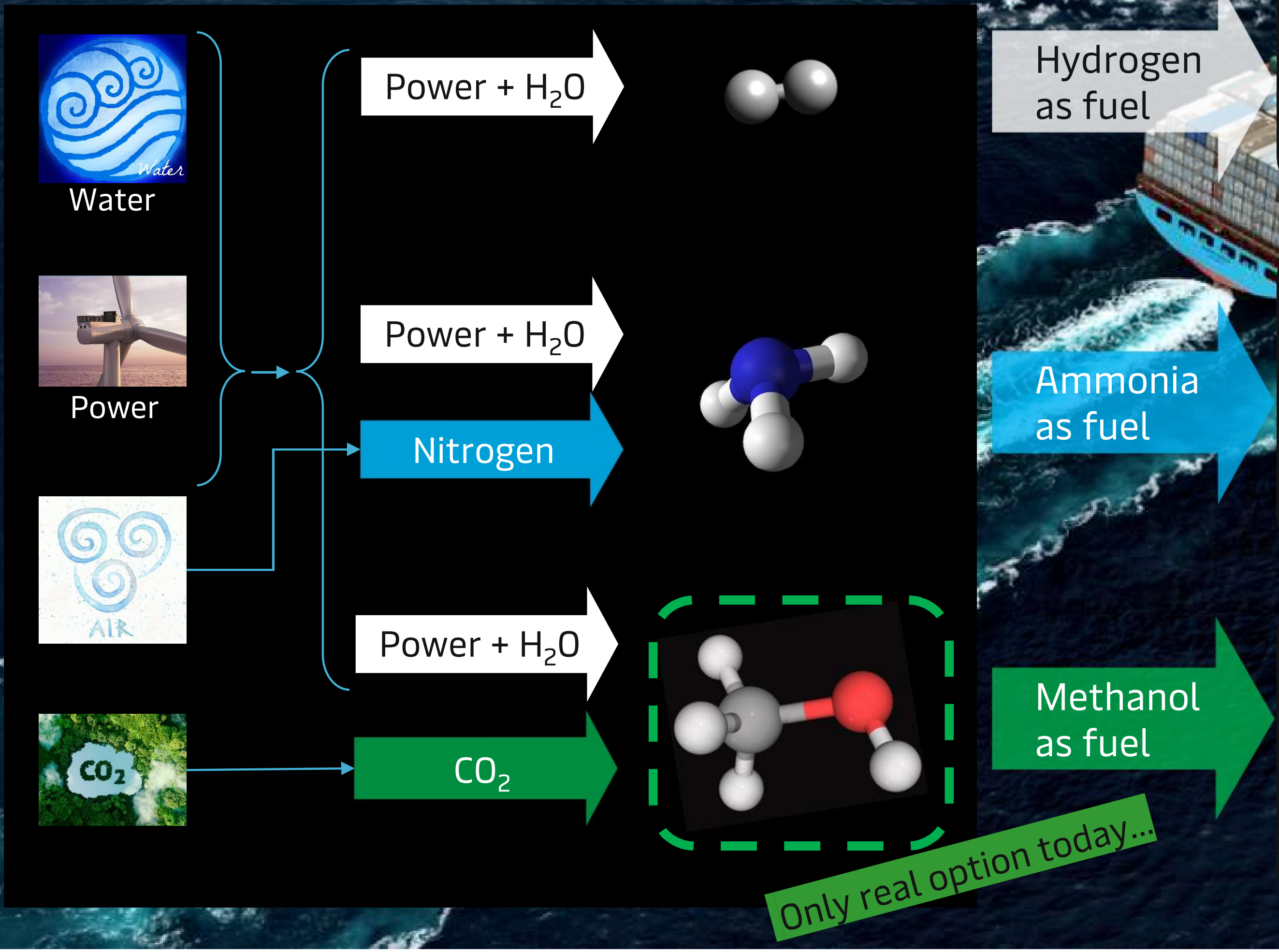
New marine fuels

Value propositions and challenges



Fuel quality:	Perfect for fuel cells
Scalability:	No carbon dependency
Physical prop.:	Light gas at room temperature
Storage/handling:	Extreme T or P
Safety:	Risk of fire and explosions
Logistics:	Expensive/Infrastructure needed
Emissions:	Water
Regulation:	Expected feasible

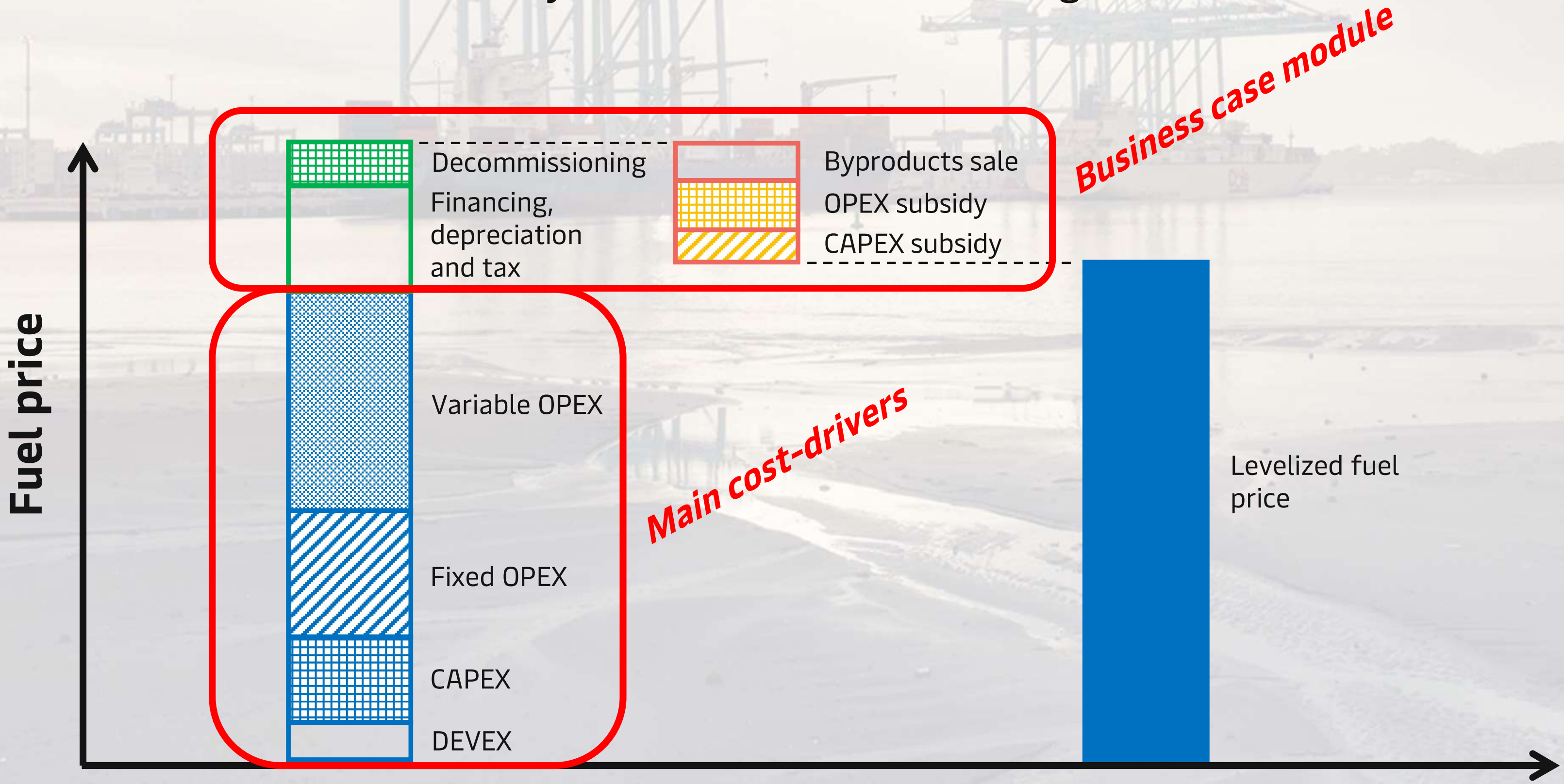
Fuel quality:	Poor
Scalability:	No carbon dependency
Physical prop.:	Gas at room temp.
Storage/handling:	Moderate T or P
Safety:	Highly toxic
Logistics:	Expensive/Infrastructure needed
Emissions:	NO_x and N_2O?
Regulation:	Uncertain

Fuel quality:	OK with pilot fuel
Scalability:	Carbon dependency
Physical prop.:	Liquid at room temperature
Storage/handling:	Relatively easy
Safety:	Flammable / Non-toxic vapors
Logistics:	Feasible/In development
Emissions:	Low NO_x, SO_x and PM
Regulation:	Feasible

Fuel costs

Techno-economic modeling

- Levelized cost of E-fuels by techno-economic modeling



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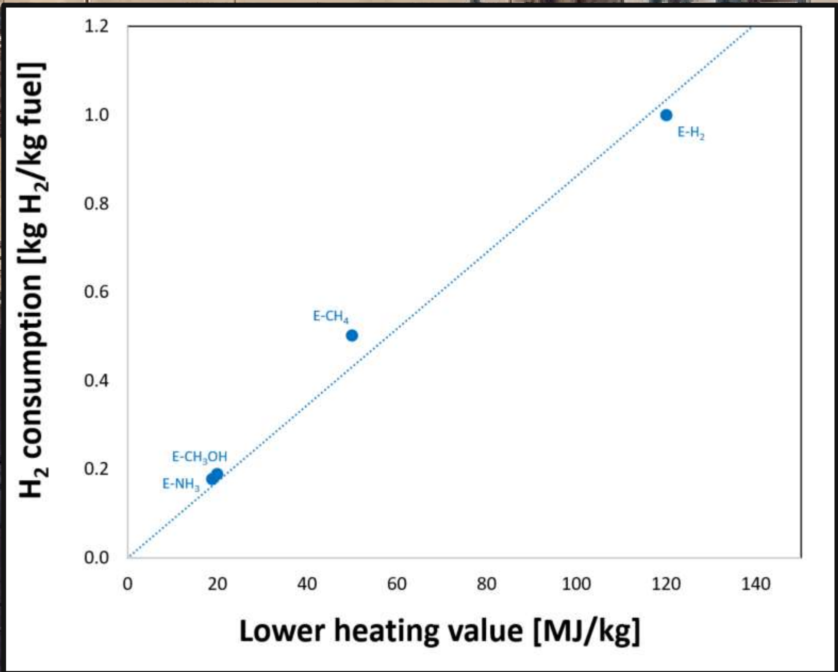
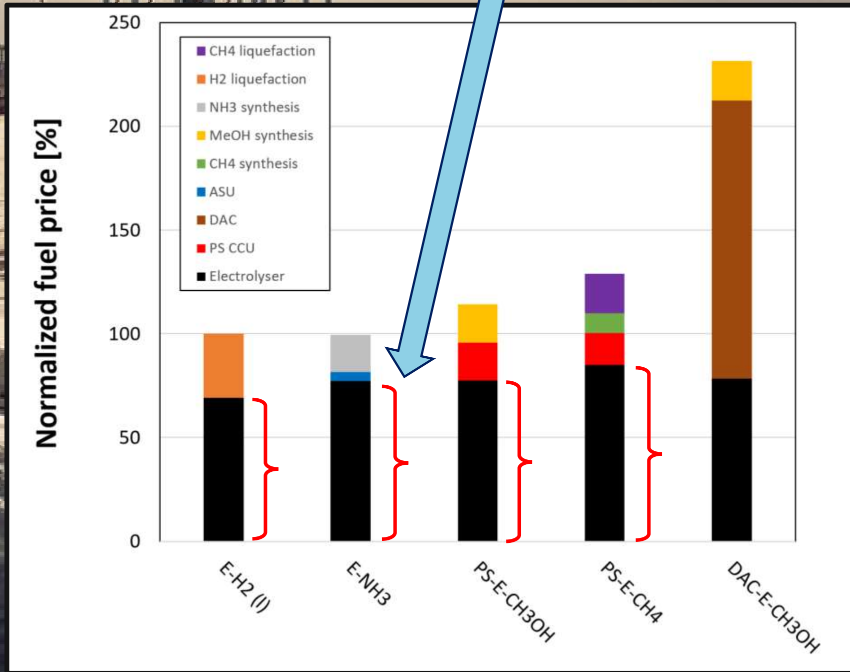
Fuel costs

Techno-economic modeling

- The relative hydrogen consumption of E-fuels is comparable.
- Fuel cost per LHV is expexted to be similar, but in the order: $E\text{-}H_2 < E\text{-}NH_3 \approx E\text{-}CH_3OH < E\text{-}CH_4$





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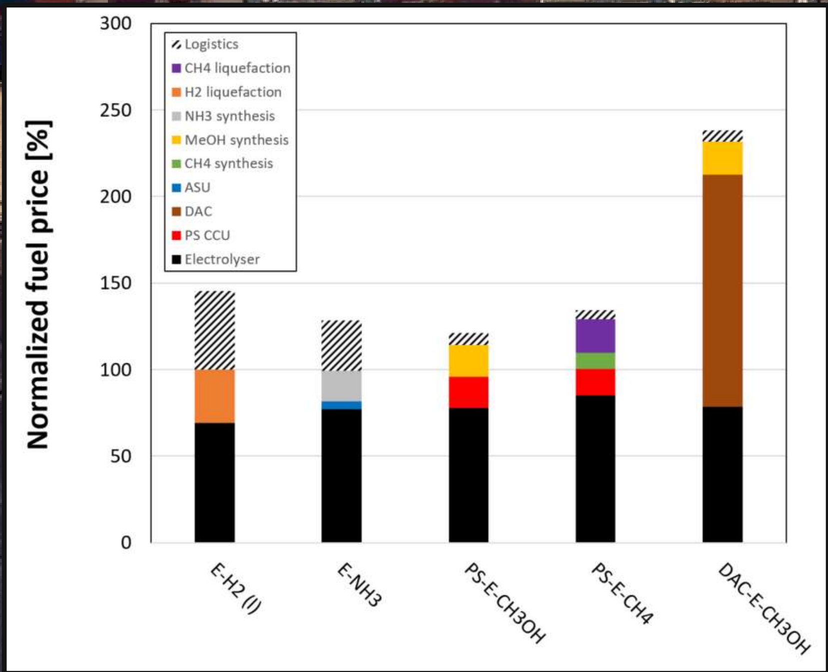
Fuel costs

Techno-economic modeling

- Fuel cost ranking may change if logistics costs are included! → Subject to high uncertainty...
- 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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Feasibility study

Hydrogen fuel cell powered feeder vessel concept

Purpose

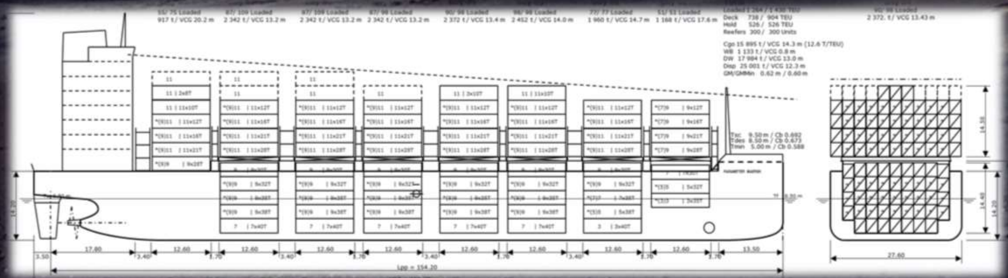
- Technical, economical and safety feasibility study of a hydrogen fuel cell powered feeder vessel using an E-methanol feeder vessel with ICE as reference.

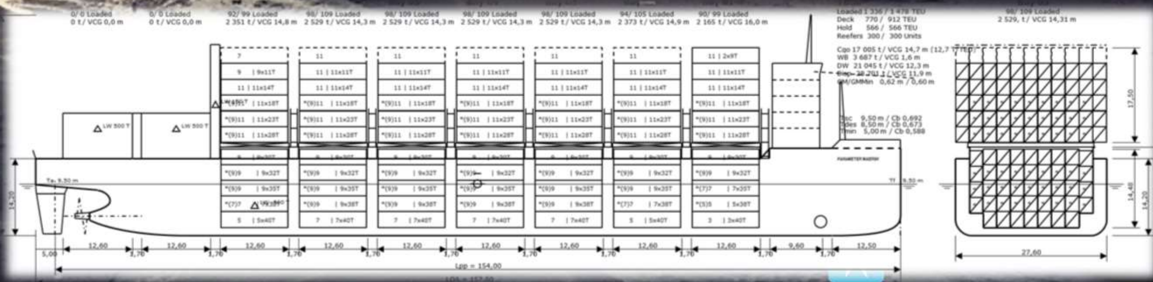
Key assumptions

- Capacity: 1000-1200 TEU with ~1/3 reefers
- Range: 2400 nm
- Ship design: Generally conventional
- Technology: Commercially available today
- Fuels: Liquid/gaseous E-H_2 and E-CH_3OH

Project team

- Maersk: Fleet Technology, Energy Transition, Network Strategy,...
- External: Lloyd's Register, Air Liquide, MAN Cryo, ABB, Ballard, TECO 2030...





Feasibility study

Hydrogen fuel cell powered feeder vessel concept

Technical feasibility:

- Pros:
  - H_2FC feeder vessel concepts are feasible "soon" using pure hydrogen as fuel when accepting a relatively limited range
  - Modular fuel cell and battery systems are available in kW to MW range
  - Indicative minor or no loss or intake/cargo (feeder size ship)
- Cons:
  - Current commercially available fuel cell systems only have efficiency comparable with ICE.
  - Fuel and storage systems for pure H_2 are complicated and expensive.
  - H_2 bunkering systems are still in development (not fully mature technology)
  - Infrastructure and H_2 bunkering systems are generally not available in ports yet.

Safety:

- High-level risk assessment of LH_2 indicates that identified risks can likely be made ALARP.
- Examples:
  - Collision events impacting storage tanks
  - Rupture of a bunker hose

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Feasibility study

Hydrogen fuel cell powered feeder vessel concept

TCO ranking:

- MeOH with ICE < LH_2 with LT-PEM (+14%) < GH_2 with LT-PEM (+22%).
- Main cost driver for the difference is significantly higher CAPEX.
- However, fuel cell technology is at the beginning of development journey whereas ICE is fully matured.

Conclusion:

- Pros:
  - A hydrogen fuelled feeder vessel seems feasible from a technical perspective.
  - Hydrogen production is scalable and has no carbon dependency.
- Cons:
  - Infrastructure for pure hydrogen is generally not in place
  - Handling of hydrogen as fuel is more complicated and expensive than methanol
  - Hydrogen has a significant risk profile making fuel and storage systems complicated and expensive.
  - Hydrogen fueled feeders are currently more expensive in TCO evaluations
  - Why should we sail on pure hydrogen if methanol if available?

Next steps

- Monitor FC technology and its development
- Exploration of alternative FC energy carriers, such as methanol and LOHC
- Explore hybrid solutions where auxiliary and reefer loads are based on FC solution (replacement of 4 stroke ICE)

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Conclusions

- Ambitious energy transition goals for Maersk's business
- New fuels offering significantly reduced GHG emissions are required
- Green hydrogen plays a key role in most fuel pathways

- Green methanol offers acceptable fuel properties and value propositions as marine fuel
- Hydrogen and ammonia are scalable (non carbon dependent) but safety, handling, logistics and regulatory challenges are to be solved.
- Levelized cost of E-fuels is comparable and even in favor of methanol if logistics are included

- Hydrogen fuelled feeder vessel concepts seem feasible from technical perspective.
- However, they are currently more expensive in TCO evaluation and come with increased safety, infrastructure and handling requirements.

- Why choose difficult alternatives to green methanol?

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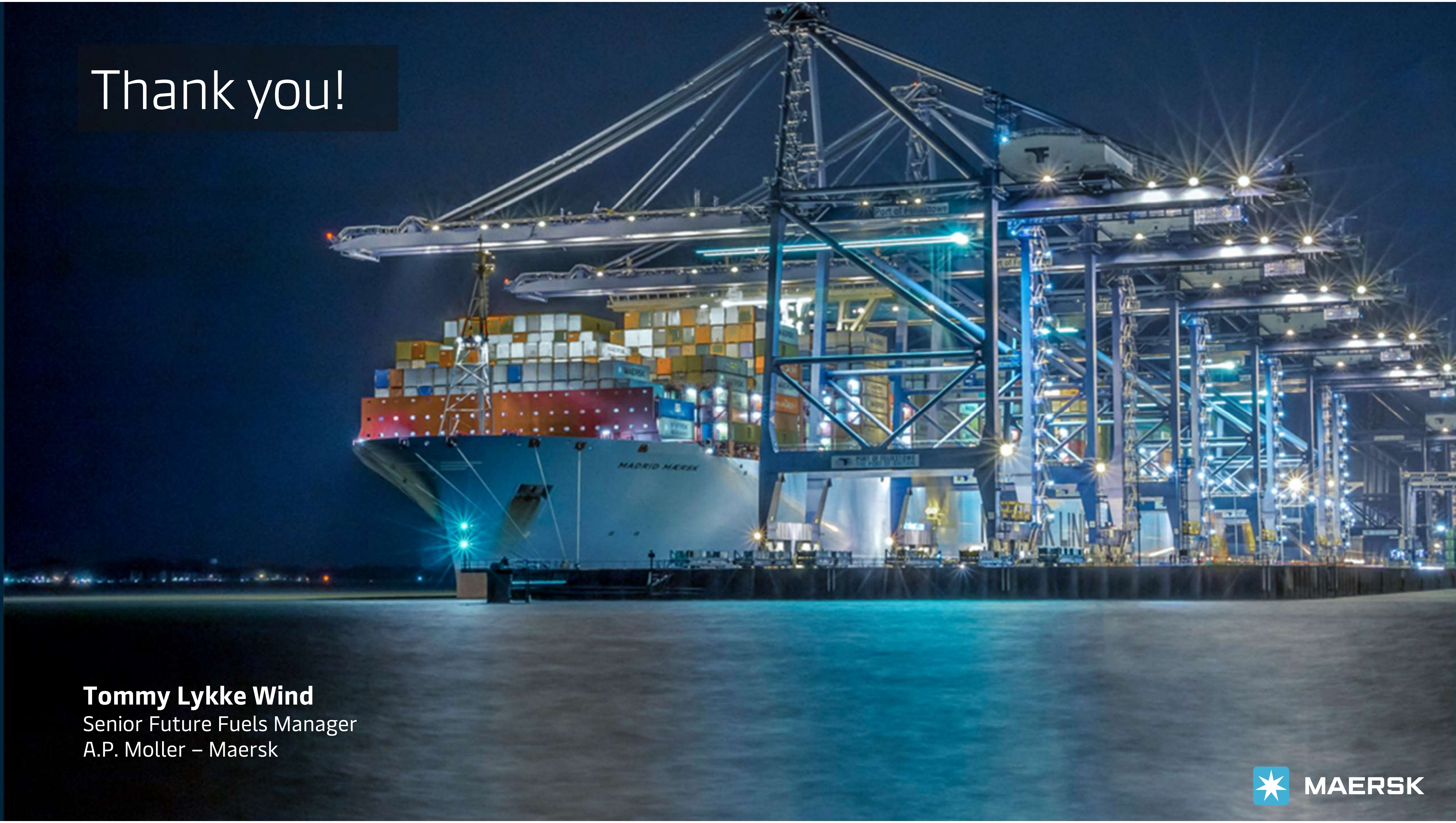
Thank you!



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