WHEN TRUST MATTERS

Economic study for decarbonization fuel strategies for a RoPax

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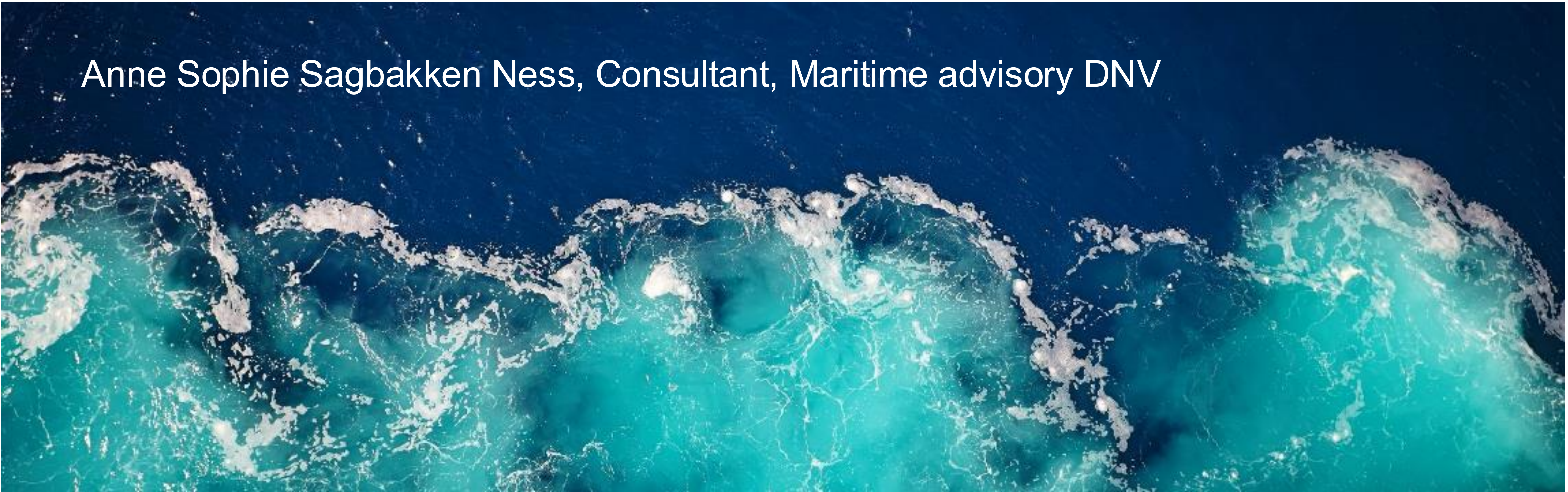


Case study input parameters

- This study has investigated the economic feasibility of different fuel and technology strategies for a 25 000 GT RoPax vessel in operation.
- We investigated the economic potential of three different fuel pathways (Fuel oil – baseline vessel, DF LNG and DF Methanol), and compared it to onboard carbon capture, where the capture unit had the capacity to **capture 80% CO2 annually** (with 30% fuel penalty).

Baseline vessel definition

Newbuild/in operation	In operation
Vessel capacity	25 000 GT
Vessel type	RoPax
Remaining lifetime	25 years
Annual sailing distance	65 000 nm
Annual fuel consumption	6500 tonnes MGO
Operation	100% within EU

Fuel retrofit strategies

Strategy 1: MF fuel oil

Fuel oil, bio-fuel

No conversion

Strategy 2: DF Methanol

Fuel oil, bio-fuel

Retrofit

Fuel oil

Green MGO

Methanol

Strategy 3: DF LNG

Fuel oil, bio-fuel

Retrofit

Fuel oil

Green MGO

LNG

Green LNG

Strategy 4: Onboard carbon capture (80% capture, 30% fuel penalty)

Fuel oil, bio-fuel

Retrofit

Fuel oil

OCCS

Green MGO

In addition all strategies has the option to pay the Tier 1 and Tier 2 cost instead of using carbon neutral fuels

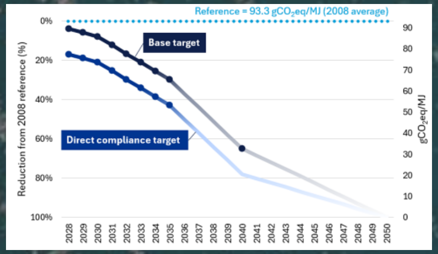
Methodology used for fuel pathway assessment

To assess the financial robustness of each decarbonization strategy, we do **scenario analysis** of the total cost of each fuel pathway. In this case study, we used five different fuel price scenarios, along with one sensitivity carbon price scenario. In each case, the strategies has to comply with IMO net zero framework, EU ETS and Fuel EU maritime.

Fuel pathway

- A – MF fuel oil
- B – DF LNG
- C – DF Methanol
- D – MF fuel oil w/onboard CCS

GHG regulations



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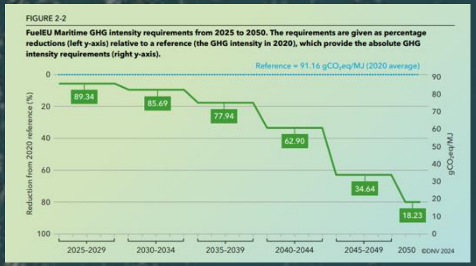

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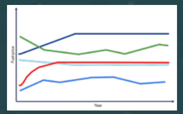
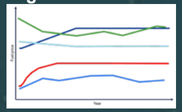
EU ETS

Fuel price scenarios

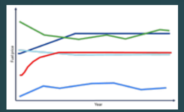
Base



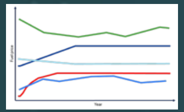
High blue fuel costs



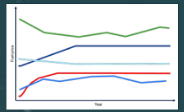
High e-fuel costs



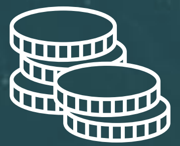
High CCS deposit costs



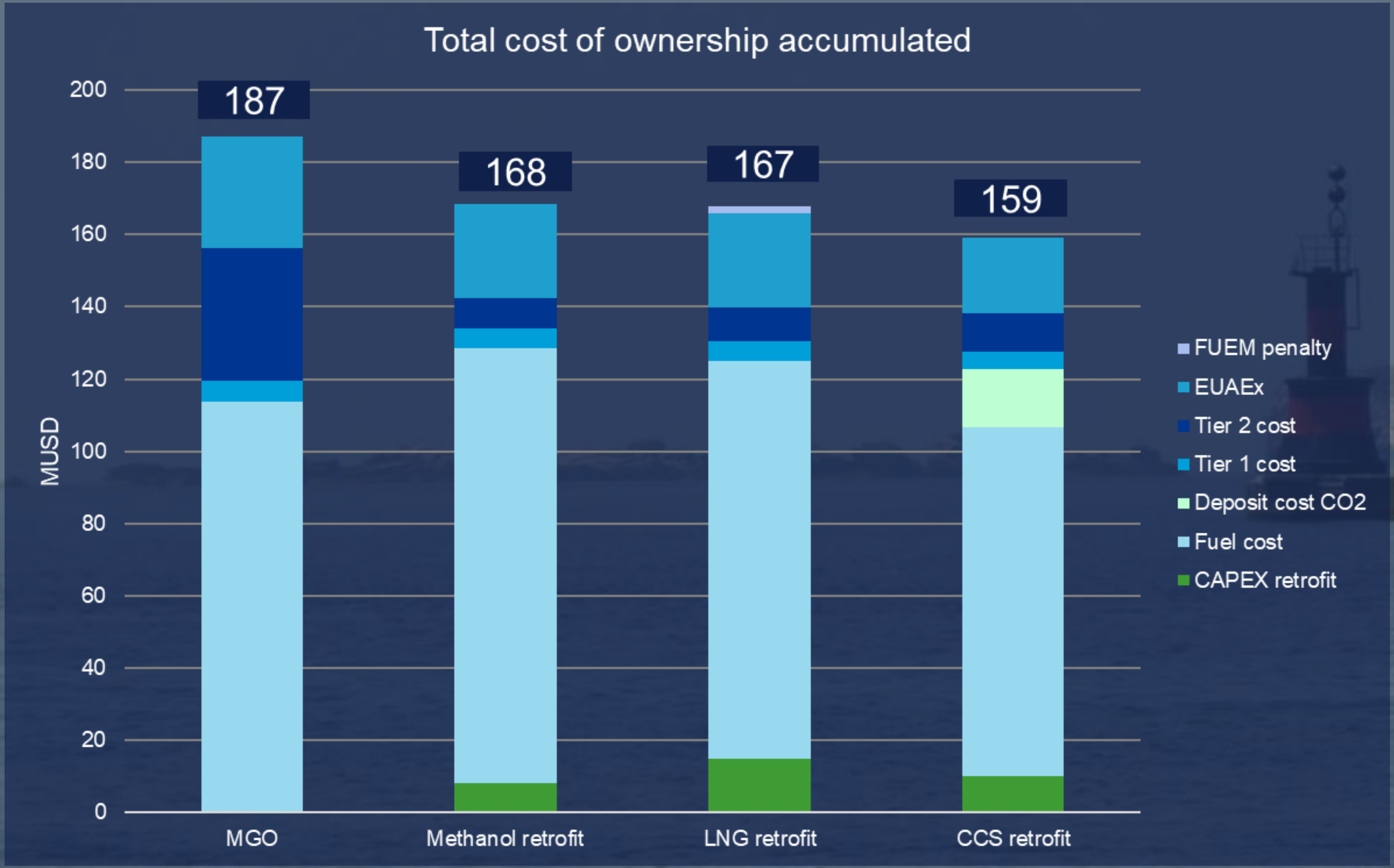
Low CCS deposit costs



Total cost of ownership



Total cost of ownership (baseline scenario)

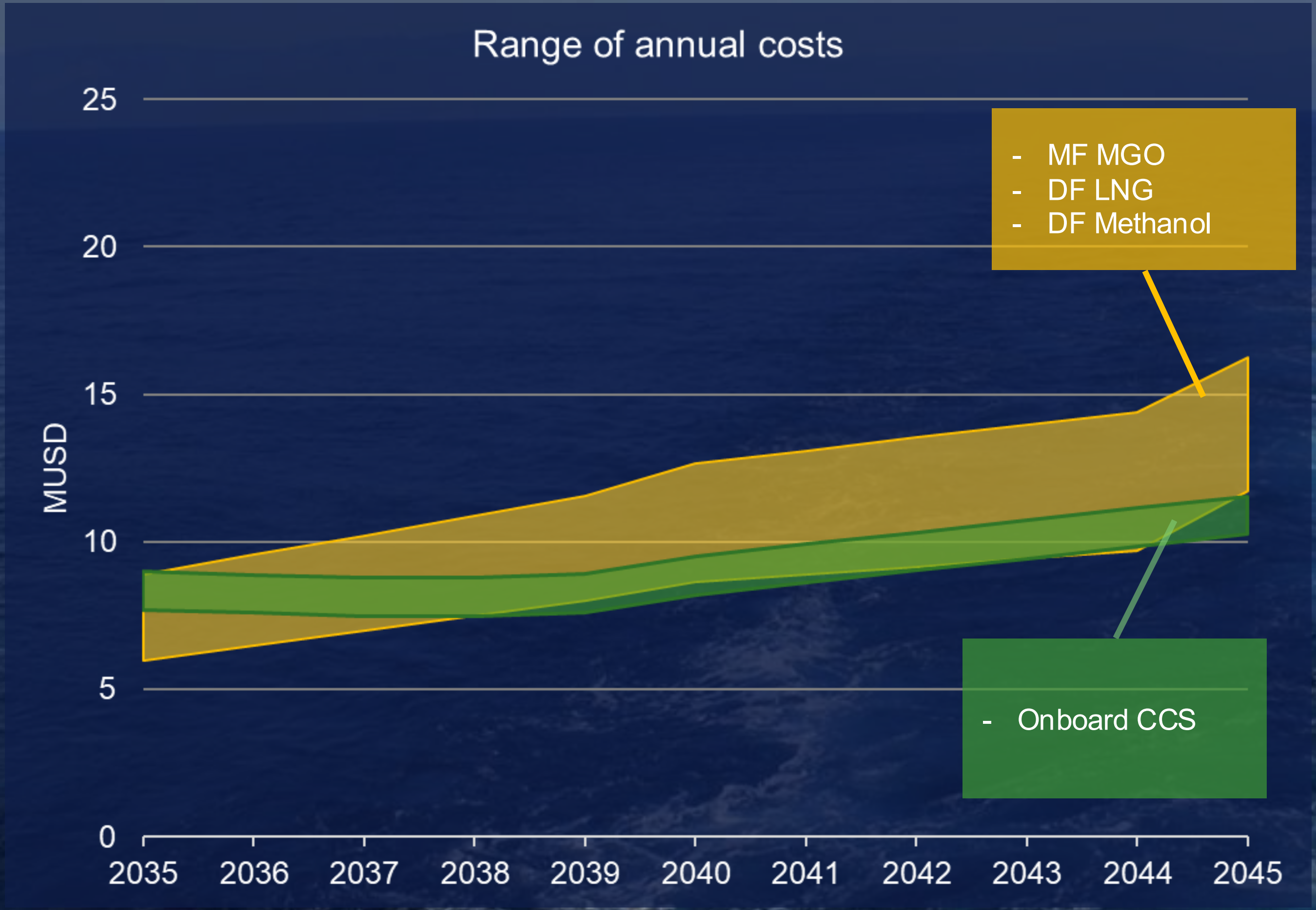


Notes on results

- FuelEU, EU ETS and NZF all included as regulations
- Doing something better than continue with conventional fuel
- Carbon capture has the lowest cost in this scenario, followed by methanol, LNG, then MGO
- CCS has lower fuel costs due to using little or no expensive carbon neutral fuels

Note: no discount rate is applied on future cash flows in the above results

Range of Annual cost



Notes on results

- The range of annual cost show that onboard CCS scenario is competitive compared to the three other fuel pathways analyzed in this study
- Annual costs for CCS are in the lower range of the technologies included in this study, especially after 2037

Note: CAPEX is not included in this graph

Operational implications

- CO_2 captured per day: about 50 m^3
- Deposit logistics, e.g. deposit every other port – 100 m^3 storage needed
- Deposit infrastructure development
- Trained crew
- Possible exploration of containerized/trailer storage onboard – technical challenges
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Technical implications

- Footprint onboard – can impact the capacity
- Weight
- Stability
- Additional fuel consumption
- Safe storage
- Retrofitting feasibility for individual ship – integration with existing machinery

Challenges and opportunities per ship segment

LNG carrier

+ Cooling load integration with LNG fuel
+ Less pre-treatment because of cleaner LNG fuel
+ Capacity for steam use in steam-driven ships

– Extra weight constraints capture rate

Tanker

+ Place on deck for the CO_2 tanks
+ Available heat production onboard

+/– Electric power plant capacity (engines and shaft generator, if any) delimits capture capacity

– Potential cargo capacity loss/max draught

Bulk carrier

+ Low steam utilization / Available heat

+/– Bigger ship bear more capacity for onboard integration. Smaller vessels have less capacities in terms of energy supply and space for tanks

– Potential cargo capacity loss / deck storage challenge. LCO_2 tank position and hatch covers opening is critical.

– Auxiliary engine capacities restrict capture rate because of liquefaction power demands

RoPax

+ Less volume because of frequent port calls. Acceptance of simultaneous operations affect business case

+/– Integration capability with locally-grown CO_2 value chains

– Less capacity for additional weight onboard

! Passenger safety and accidental stored CO_2 release is an issue. Affect location of the temporary CO_2 storage location.

Container

+ Less volume required because of frequent port calls. This benefit is expected when a global CCUS chain is fully developed.
+ Bigger vessels connecting major shipping hubs may have access to the growing CCUS value chain.

+/– Frequent port calls for smaller feeders. But possibly less timing for CO_2 offloading. Challenge tackled with simultaneous operations.

+/– Space for OCC components comes at a premium – due to the potential loss of boxes. But cargo load factor may support the business case.

With the carbon capture inclusion, the design requires reassessment in terms of stability, strength, visibility and safety, to ensure, among other things, the presence of safeguards, safe passages, and maintenance routes.

Onboard arrangements will, however, differ between capture method and ship type.

DNV

Challenges and opportunities per ship segment

RoPax

+

Less volume because of frequent port calls. Acceptance of simultaneous operations affect business case

+/–

Integration capability with locally-grown CO_2 value chains

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Less capacity for additional weight onboard

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Passenger safety and accidental stored CO_2 release is an issue. Affect location of the temporary CO_2 storage location.

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Conclusions

This study shows an **advantage for the alternative fuels** compared to conventional

Onboard carbon capture can compete with other decarbonization solutions for a Ro Pax Ferry – depending on fuel prices, carbon cost and deposit cost and regulatory acceptance

Tanks of ~100 m^3 will be sufficient to store the captured CO_2 from 2 days of voyage for the case study vessel

Ro Pax have an advantage when it comes to CCS due to frequent port calls – need smaller tanks

Passenger safety and additional weight are technical barriers

Thank you!

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