Ammonia as a ship fuel: transition pathways

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Who are we?

…focus on research and consultancy

2000's Now 2050

Evidence of recent trends in energy efficiency

Using big data to understand trends and drivers of shipping activity, energy demand/emissions

Evidence of how the future of energy efficiency/GHG might look

Using models to explore what-ifs for future market and policy

Summary

1. Decarbonisation of shipping – IMO Goals
2. Ammonia as a ship fuel – a key marine bunker?
3. Production of marine ammonia (brown>blue>green)?
4. Next steps?
5. Key takeaways

Shipping and climate change – decarbonisation on the horizon

IMO 'Initial Strategy' on GHGs…

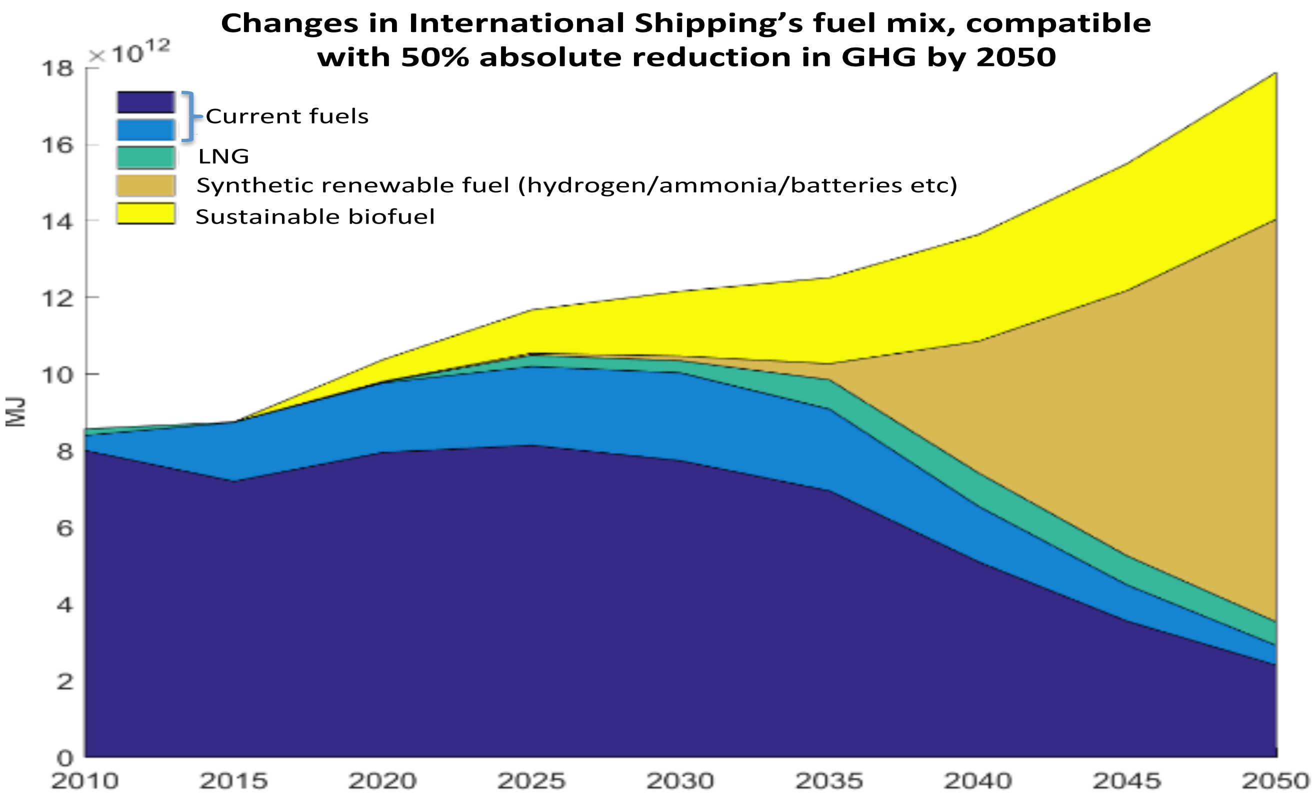
2015

2018

IMO IS - three levels of ambition:

1. Decline of ship carbon intensity through further EEDI measures
2. Decline of international shipping carbon intensity (reduce CO2 per transport work)
3. **GHG emissions to peak and decline - reduce total GHG emissions by at least 50% by 2050, and pursuing efforts towards 70% reduction compared 2008.**

Fuel mix in line with IMO initial strategy…

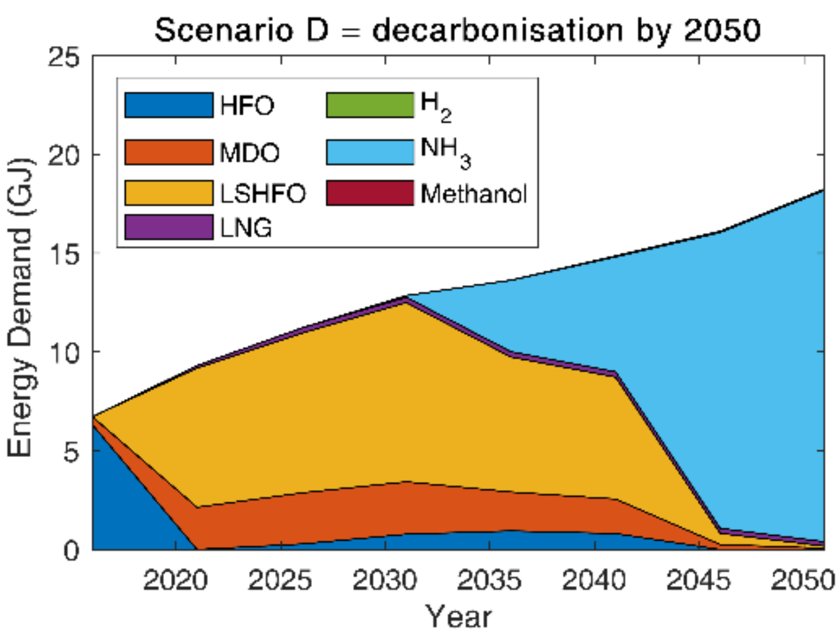


Adapted from Belgium et al. ISWG 1 INF.2

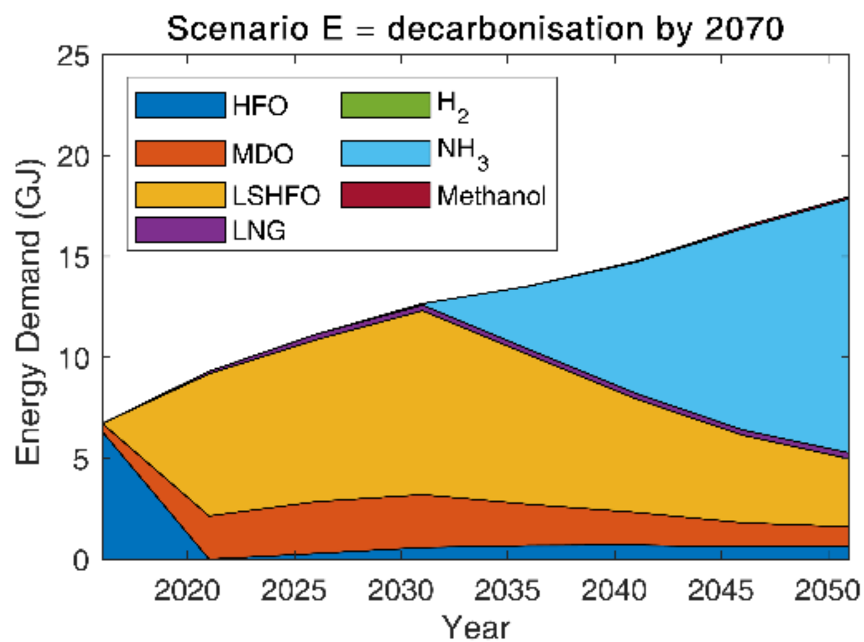
What does this mean for marine fuels?

Scenario analysis suggests a leading role for ammonia with rapid growth post 2040 and between 75-99% market share by 2050

2050 decarbonization (1.5°C aligned)
GJ



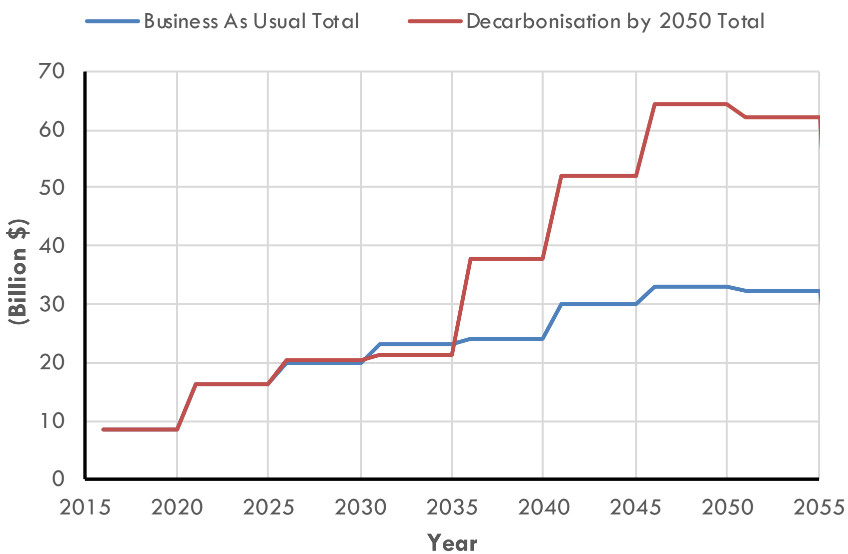
2070 decarbonization (IMO aligned)
GJ



The scenarios suggest ammonia is likely to represent the least-cost pathway for international shipping

Source: UMAS GloTraM (2019)

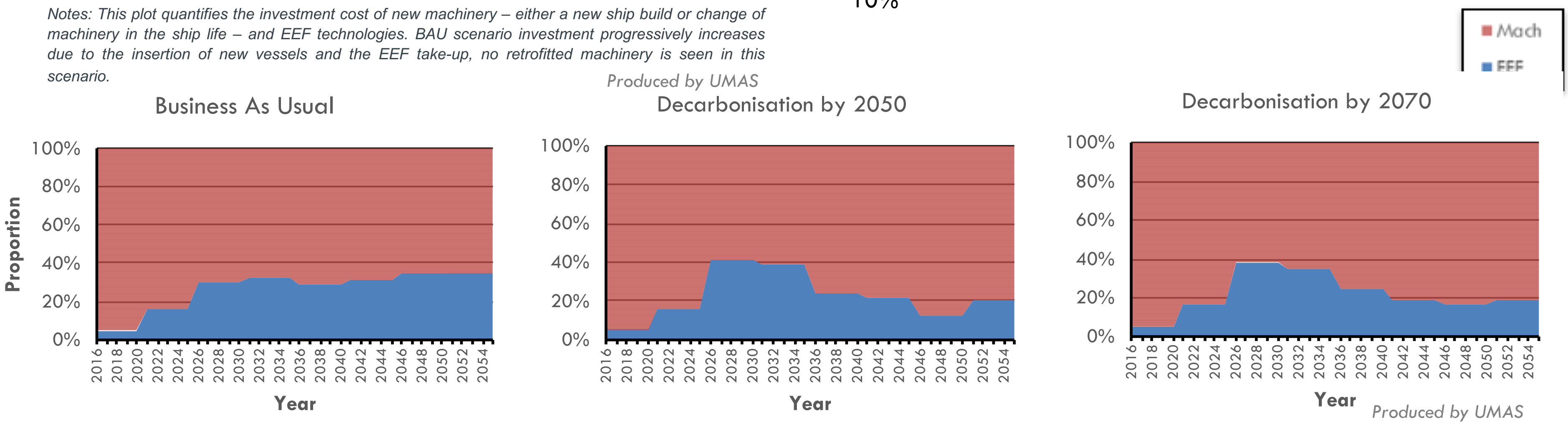
The switch to other fuel/engine is the main driver of the decarbonisation.



Notes: This plot quantifies the investment cost of new machinery – either a new ship build or change of machinery in the ship life – and EEF technologies. BAU scenario investment progressively increases due to the insertion of new vessels and the EEF take-up, no retrofitted machinery is seen in this scenario.

Produced by UMAS

- The capital cost for the machinery includes the cost of the engines and of the fuel storage system
- The machinery cumulative investment represents 72% of the total investment costs for shipping (machinery plus EEF technologies costs) for BAU scenario, 79% for the decarbonisation by 2050 scenario and 80% for decarbonisation by 2070 scenario.
- In both decarbonisation scenarios, there is a significant switch to ammonia used in an internal combustion engine; this reflects the higher investment costs in these scenarios.
- The machinery for an ammonia vessels is estimated to cost twice more than the conventional 2-stroke engine with HFO tank.
- As illustrative example, the figures shows the trend over time of annual amortized investment costs using an interest rate of 10%



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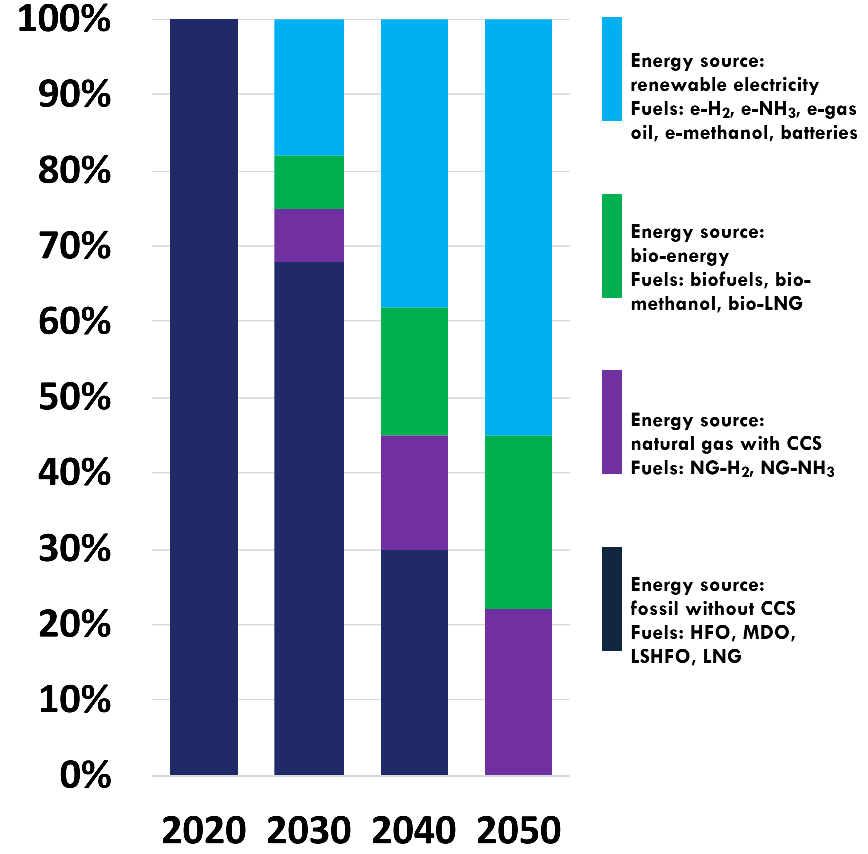
Natural gas or renewable electricity as marine NH3 feedstock?

Renewable electricity as feedstock?

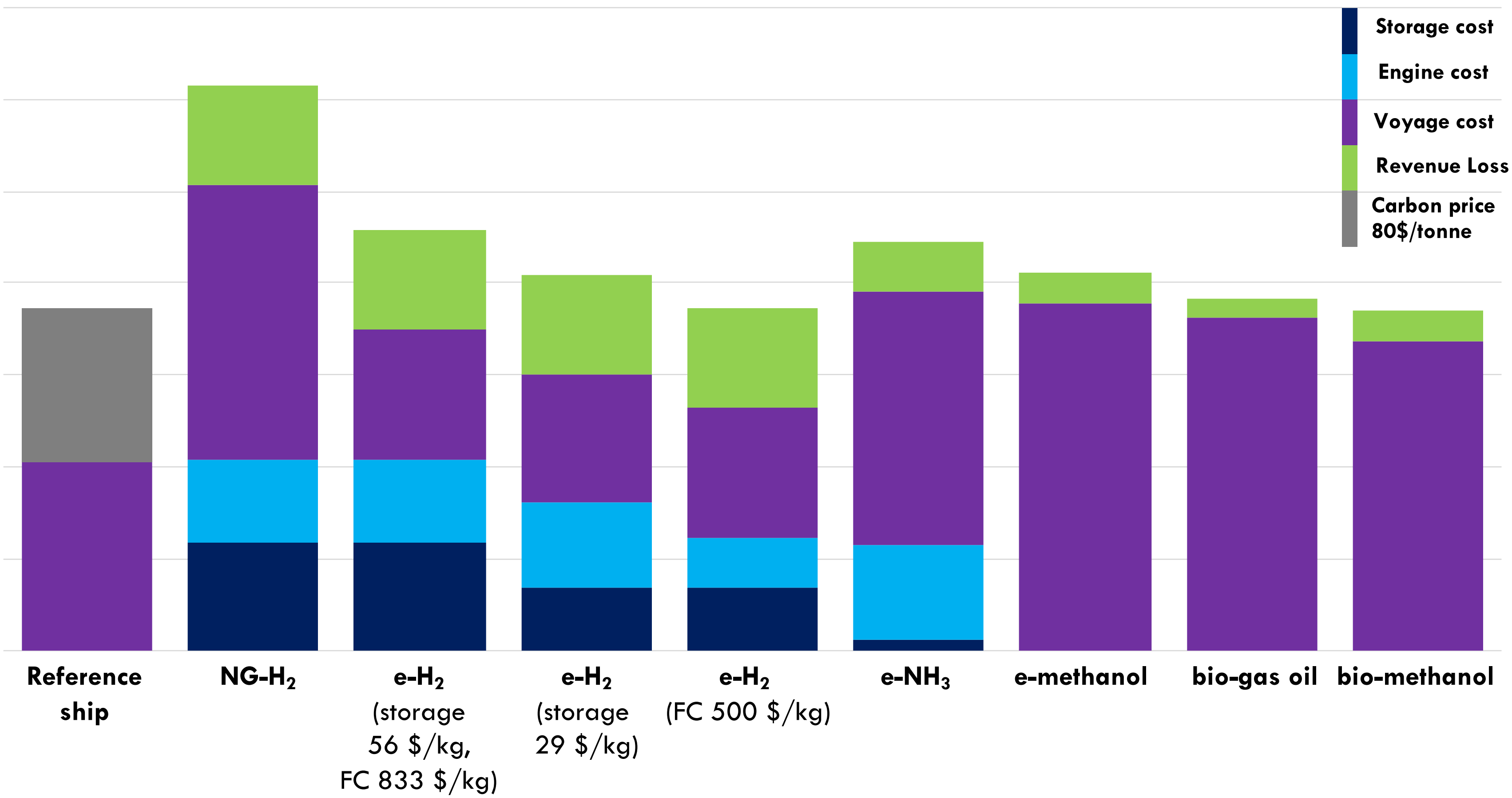
- Global network of H2/NH3 bunkering, and affordable RE production.
- At a price of 19 $/MWh, RE fuels as competitive as bio-based fuels.
- e-NH3 or e-H2 main fuels, dependent on H2 storage system development, and trade-offs.



*LR UMAS (2019). *Zero-Emission Vessels: Transition Pathways*

NH3 could be competitive…

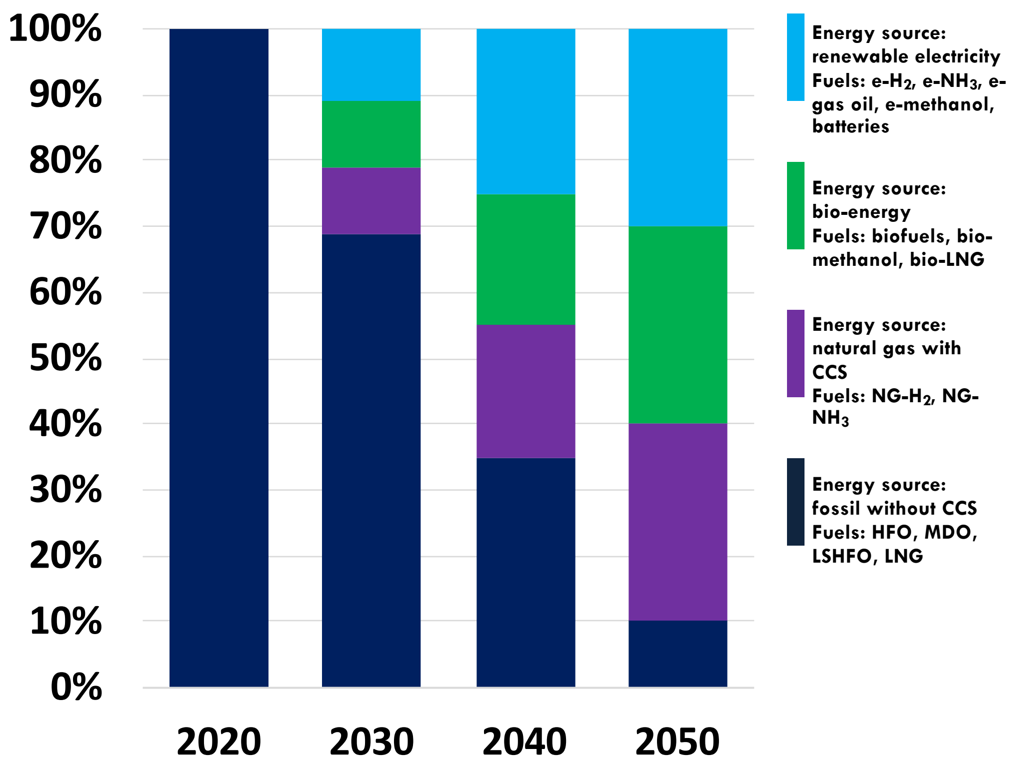
- e-NH3 competitive with E-H2 and e-methanol, lower storage costs
- Linked to development of storage
- Benefits compared to H2



LR UMAS (2019). Zero-Emission Vessels: Transition Pathways

NG as feedstock?

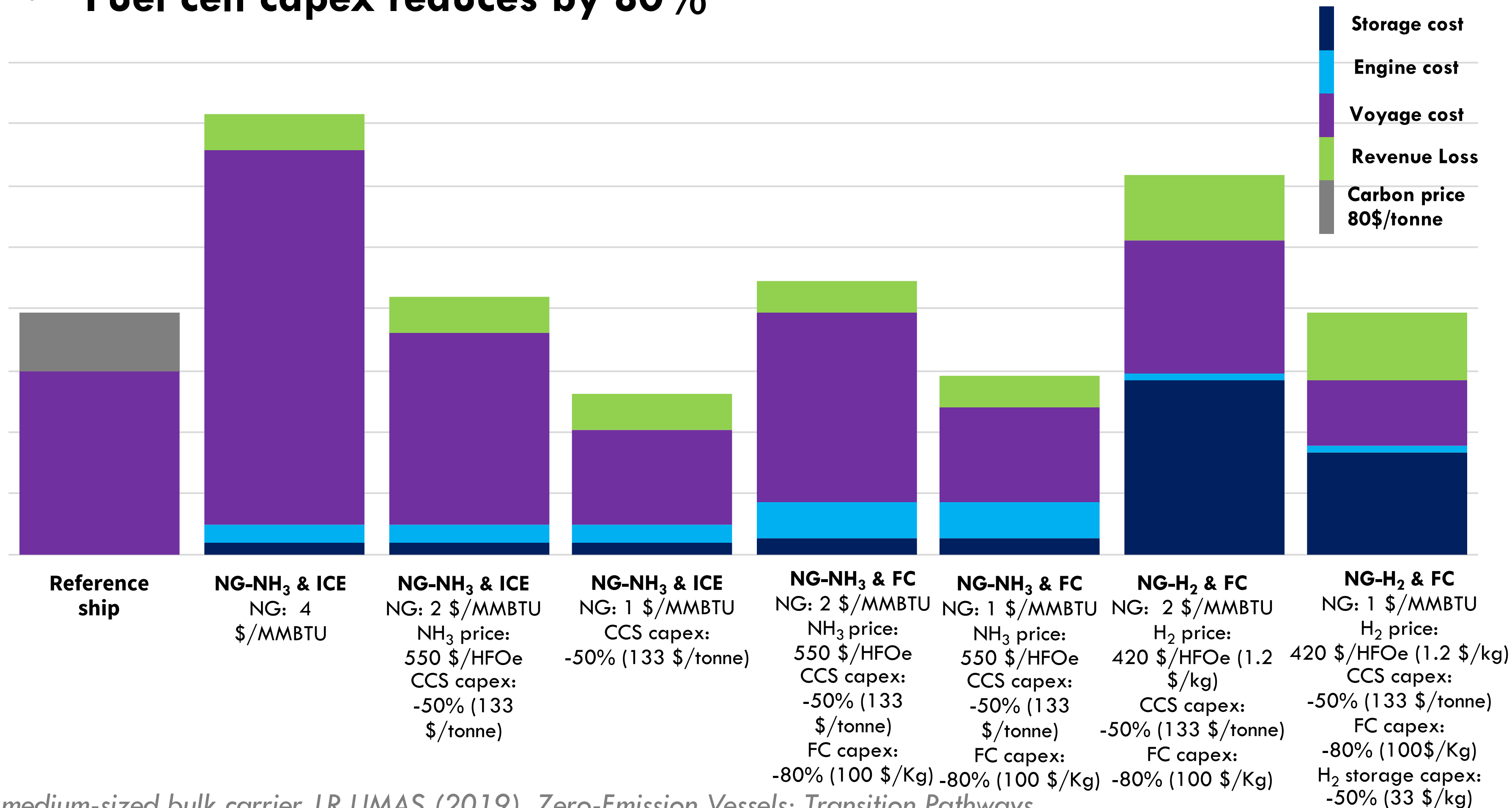
- NG plays an important role in society, beyond marine
- Availability of affordable NG and CCS need to be developed, with capex reducing about 50%
- NG CCS not dominant - limited CCS energy capacity under the 1.5°C pathway



LR UMAS (2019). Zero-Emission Vessels: Transition Pathways

NH3 could be competitive…

- Price of NG reduces from $ 4/MMBTU to $ 1/MMBTU
- CCS capex reduces by 50%
- Fuel cell capex reduces by 80%



**medium-sized bulk carrier, LR UMAS (2019). Zero-Emission Vessels: Transition Pathways*

Carbon Capture & Storage (CCS) vs Renewable Electricity (RE)

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CCS

- High costs, perception, technology lock-in, residual emissions and legal challenges
- Large range in costs for capture, transport and storage
- Cannot be a long-run solution except in closed-loop applications

RE

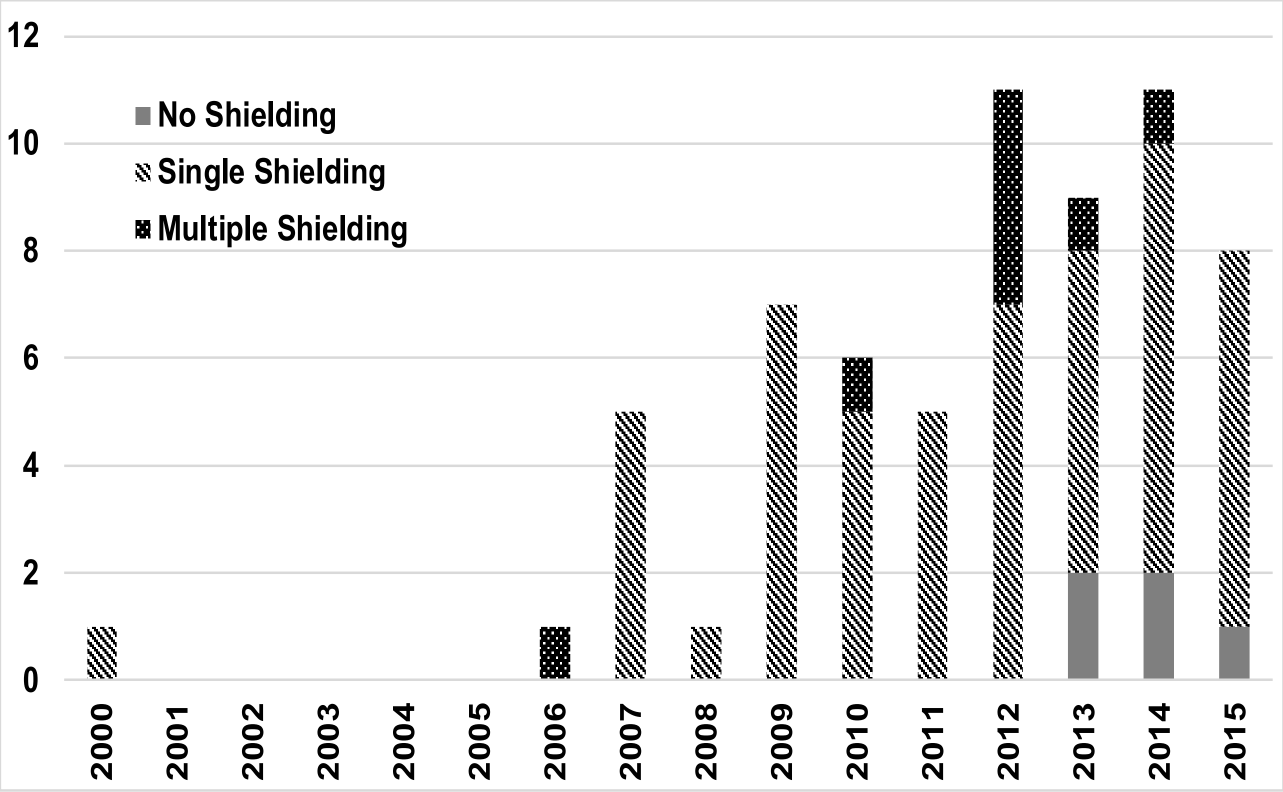
- RE production has to be scaled up rapidly
- Should be a long-run solution, as the only long-term sustainable solution
- Develop clear understanding of development and transition pathways to green NH3

Where do we go from here?

Early stages of the transition – mobilizing resources

- How to facilitate early uptake of NH3 as a marine fuel?
- How to scale up pilots>deployment>viable markets?
- Develop 'sustainability indicators' to trace success of low carbon marine fuel diffusion?

LNG vessels funding/support



Baresic, D. (2019). Sustainability transitions in maritime transport: the case of LNG in northern Europe, UCL

Chicken and egg problem – starting transition in favourable locations

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- Limited understanding of how to support NH3 bunkering infrastructure development
- What geographic niches offer best support for early transitions?
- How to avoid chicken and egg problem?
- How to transition brown>blue>green ammonia>

LNG Bunkering infrastructure funding/support

Location:	ST Environment:	Development:	Initiation-Completion:	Shileding: Norway	Sweden	Finland	Denmark	Net	Netherlands	EU
Tjeldbergodden	Norway	LNG Facility (R&D)	1994-1997	X						
Kollsnes	Norway	LNG Terminal	2003							
Snurrevarden	Norway	LNG Terminal	2004							
Risavika	Norway	LNG Terminal	2007-2010							
Snohvit	Norway	LNG Terminal	2002-2007	X						
Ora-Fredrikstad	Norway	LNG Bunkering Facility	2011							
N/A	Denmark	Study/Network (GO LNG Network)	2010-2012							X
Hirsthals	Denmark	LNG Bunkering Facility	2014-2015							X
Fredrikshavn	Denmark	LNG Bunkering Facility	2015-Post 2015							X
Nynäshamn	Sweden	LNG Terminal	2008-2011							
Lysekil	Sweden	LNG Terminal	2011-2014							X
Stockholm	Sweden	LNG Bunker Vessel	2012-2013							X
Brofjorden	Sweden	LNG Bunkering Facility	2012-2015							X
Gothenburg	Sweden	LNG Bunkering Facility	2012-2015							X
Kilpilathi	Finland	LNG Facility (R&D)	2006	X						
Pori	Finland	LNG Terminal	2013-Post 2015			X				
Rauma	Finland	LNG Terminal	2014-Post 2015			X				
Tornio	Finland	LNG Terminal	2014-Post 2015			X				
Rotterdam	Netherlands	LNG Terminal	2005-2011							
Rotterdam	Netherlands	LNG Bunkering Facility	2012-2015							X
Wadden Sea	Netherlands	LNG Bunkering Facility	2013-2015							X
Rhine	Netherlands	LNG Bunker Vessel	2012-2013							
N/A	Wide	Study/Network (DMA Study)	2010-2012							X
N/A	Wide	Study/Network (LNG Baltic Sea Ports)	2011-2014							X
N/A	Wide	Study/Network (LNG Masterplan)	2012-2014							X
Baltic Sea	Wide	LNG Bunker Vessel	2012-2015							X

Baresic, D. (2019). Sustainability transitions in maritime transport: the case of LNG in northern Europe, UCL

Key takeaways…

Key takeaways…

- Significant additional NH3 production capacity will be required ~450-500mt p.a. for shipping (by 2050 assuming 20EJ demand)
- Mid-term NG+CCS production pathway potentially viable, but long-term RE is only option
- NH3 has potential to be a key marine bunker fuel within the next 20 years
- NH3 could offer significant investment opportunities as a marine fuel

What's next?

- Further study needed to understand how NH3 transition can take place
- Analysis of best geographic areas for early adoption of marine NH3 needed, as these could jump-start adoption
- Detailed understanding of NH3 transition pathways and associated costs/prices still required

Questions?

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