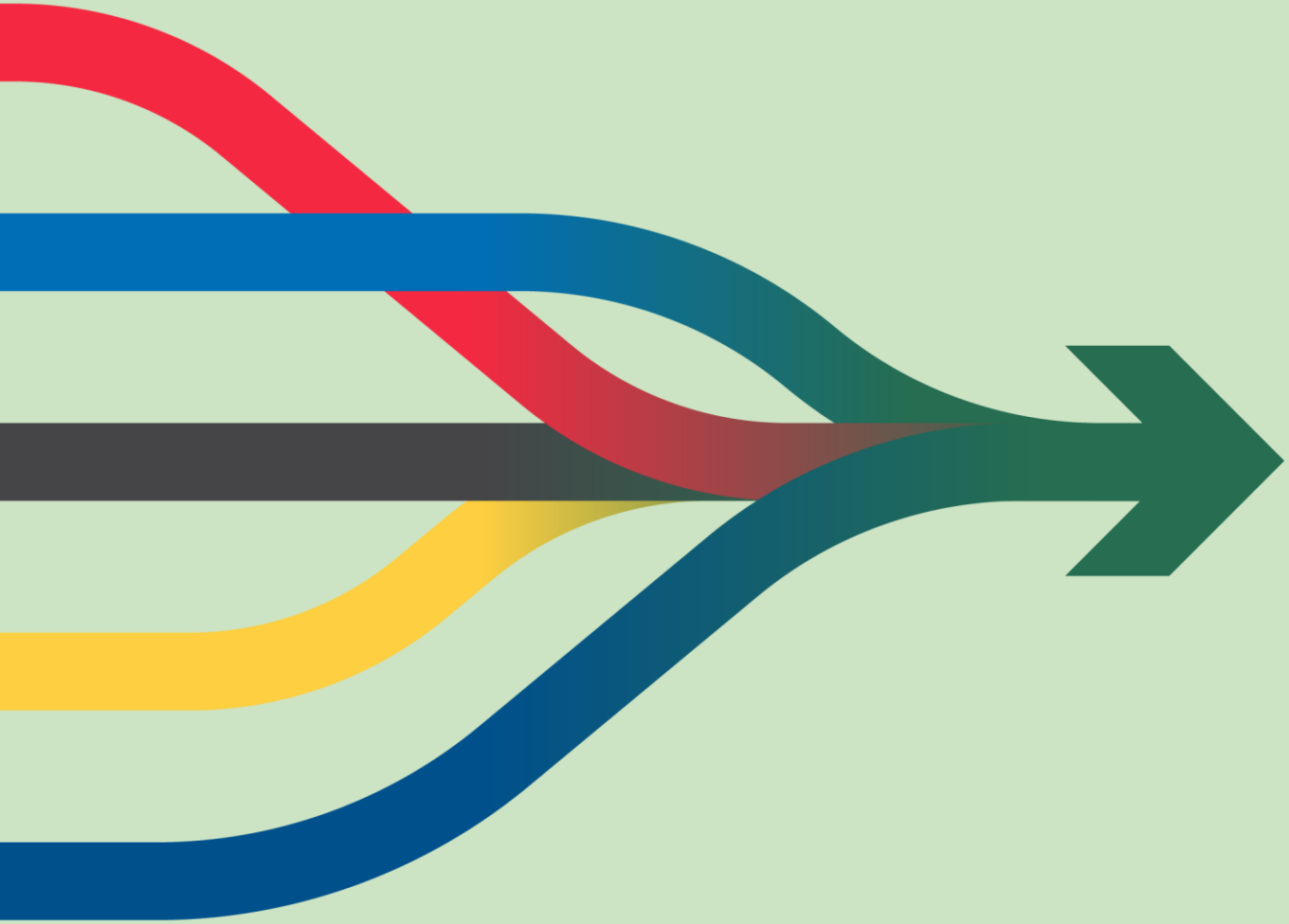

HOPE – On the Potential for Hydrogen based Solutions for Shipping

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Nordic Energy Research

Nordic Energy Research

HOPE - analyzing the potential role of marine hydrogen fuel cells solutions for regional shipping in the Nordic region

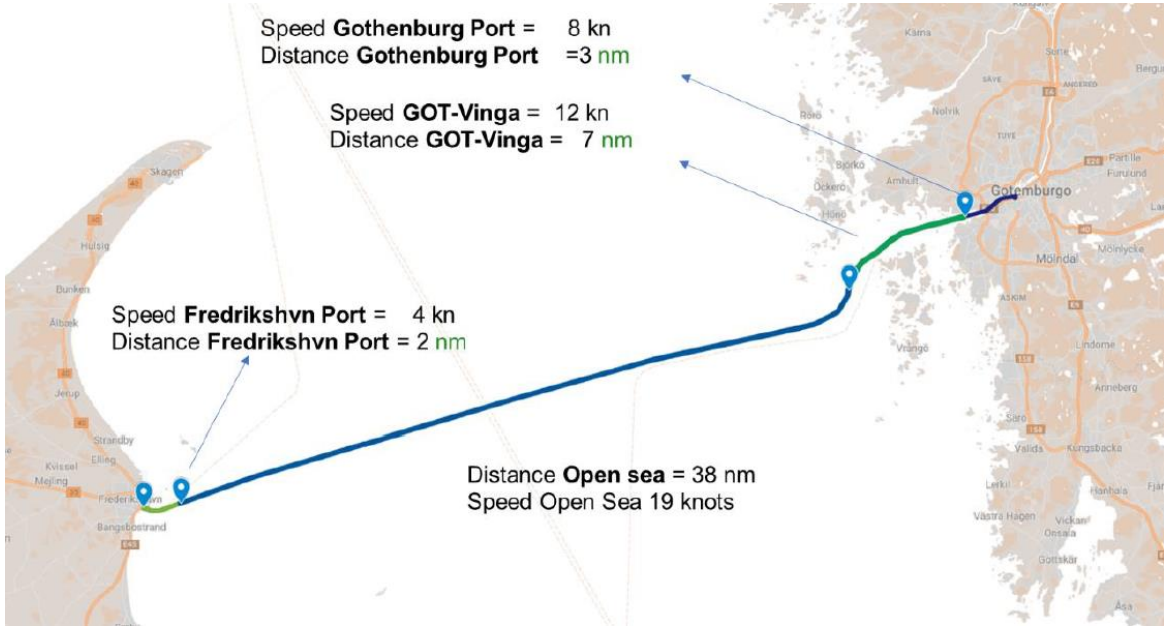
HOPE outlines and evaluates a concept design for a short sea shipping vessel using hydrogen and fuel cells for propulsion…

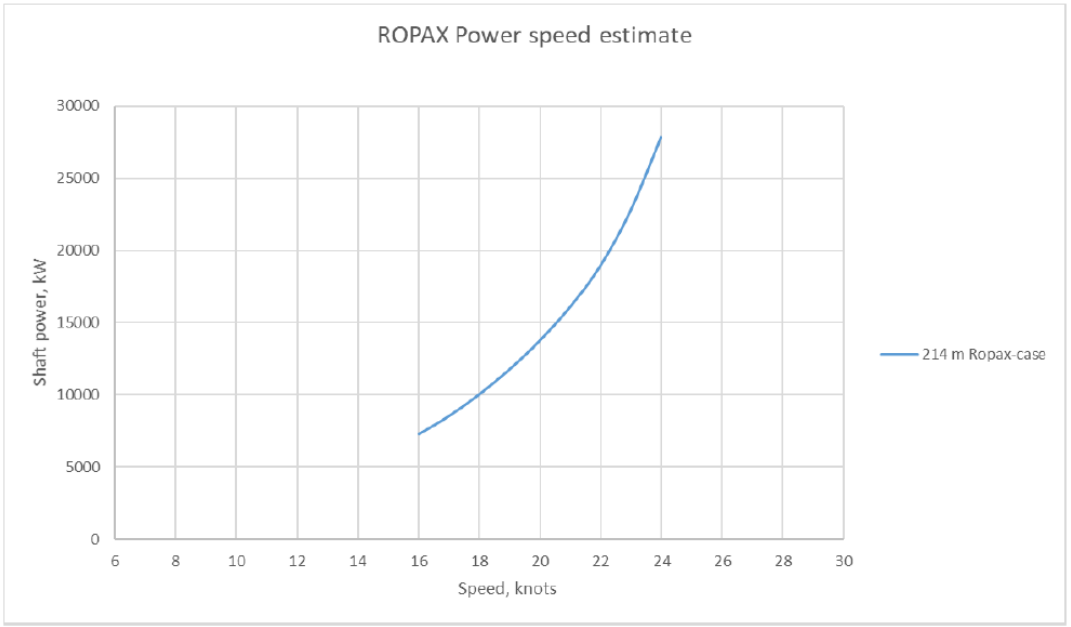
…including technical and cost aspects, barriers for and environmental impact of realization in the Nordics.

https://www.nordicenergy.org/project/hope/ + https://www.ivl.se/projektwebbar/hope.html

Funded by Nordic Energy Research, Swedish Transport Administration, Norwegian Research Council, Icelandic Research Center, Danish EUDP, Business Finland and in-kind from participating companies. 2021-2023

Case study: Gothenburg (SE)-Fredrikshavn (DK) route

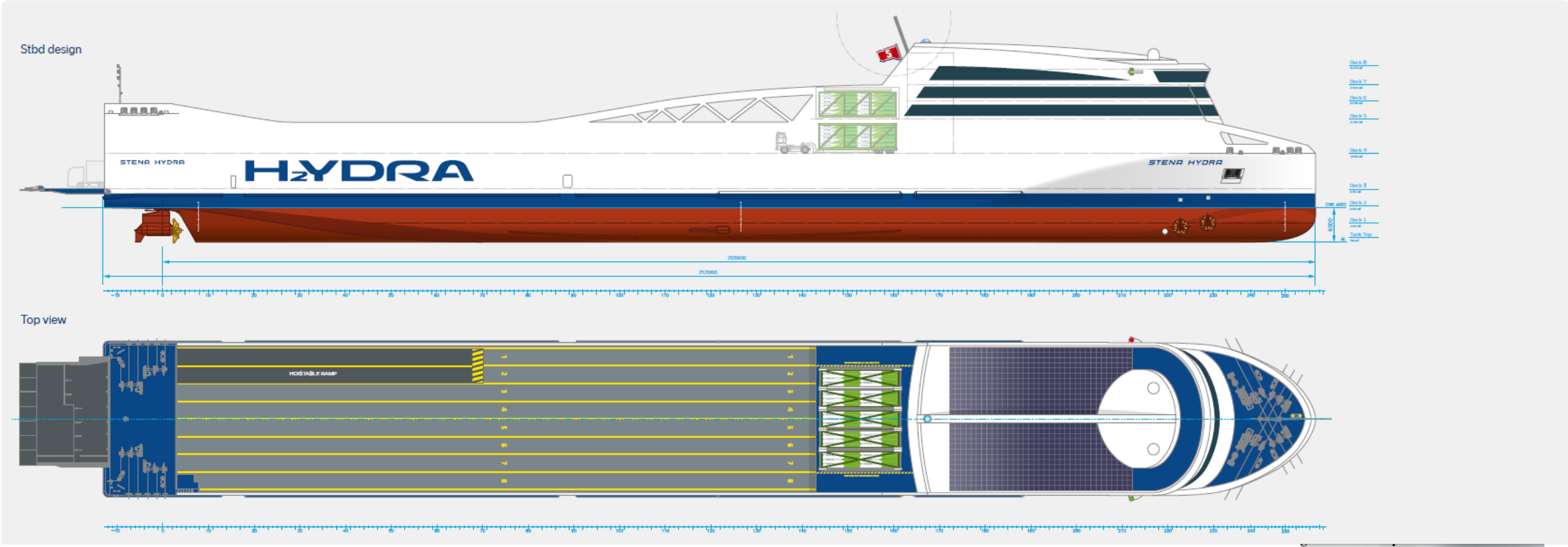




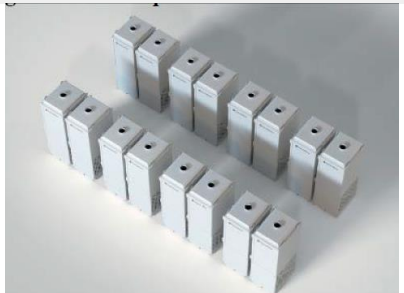
- Route data based on present RoPax service
- Route modeling by SINTEF
- Initial vessel design by Stena Teknik

Concept design: General Arrengement (GA) - Stena Hydra

PROPOSAL

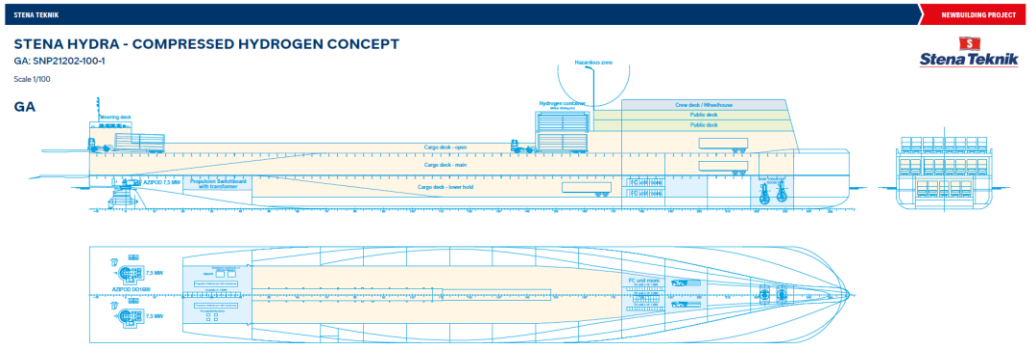


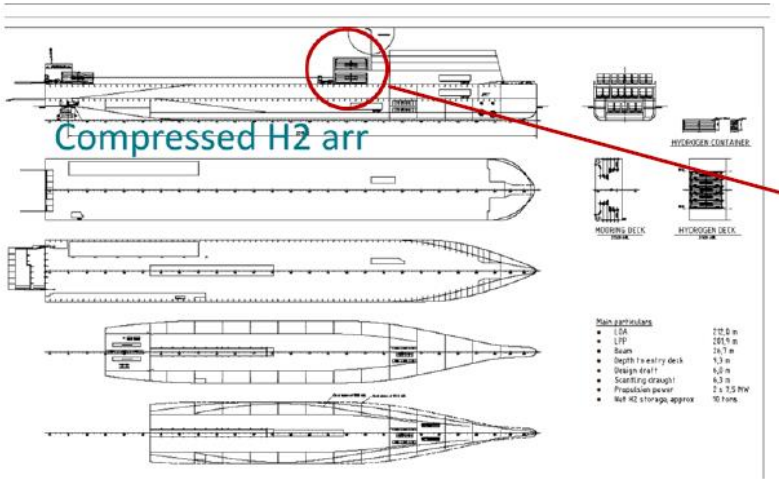
Propulsion system: fuel cells (PEM) running on hydrogen (PowerCell Sweden, 200 kW Modules, 80 units for 16 MW)

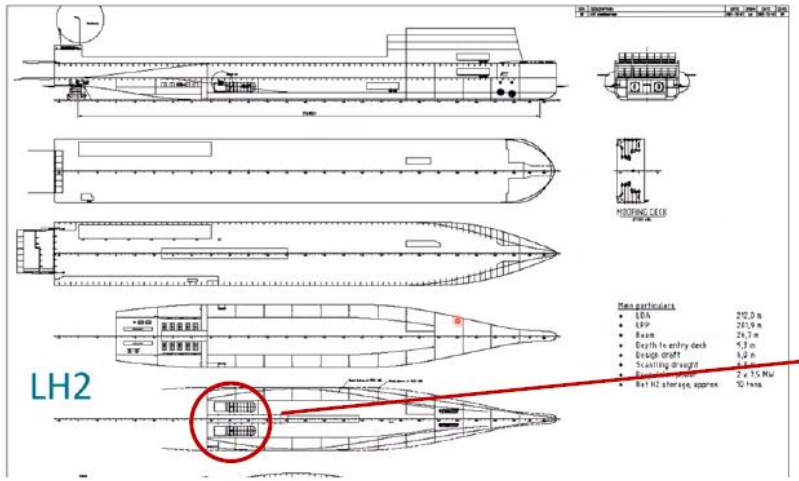


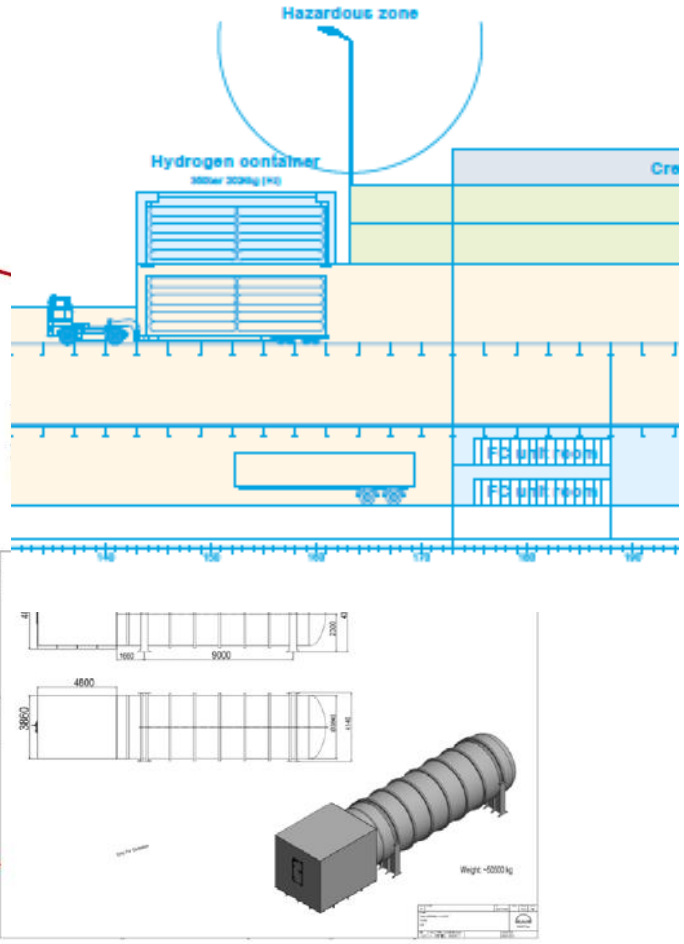
Nordic Green Transport Forum

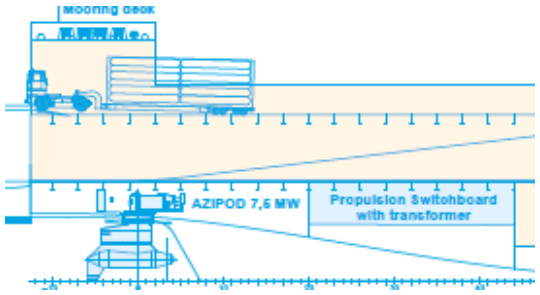
Compressed or liquid hydrogen?

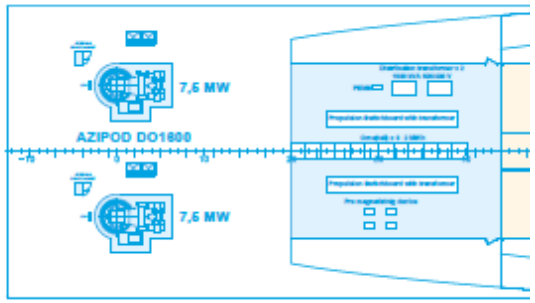








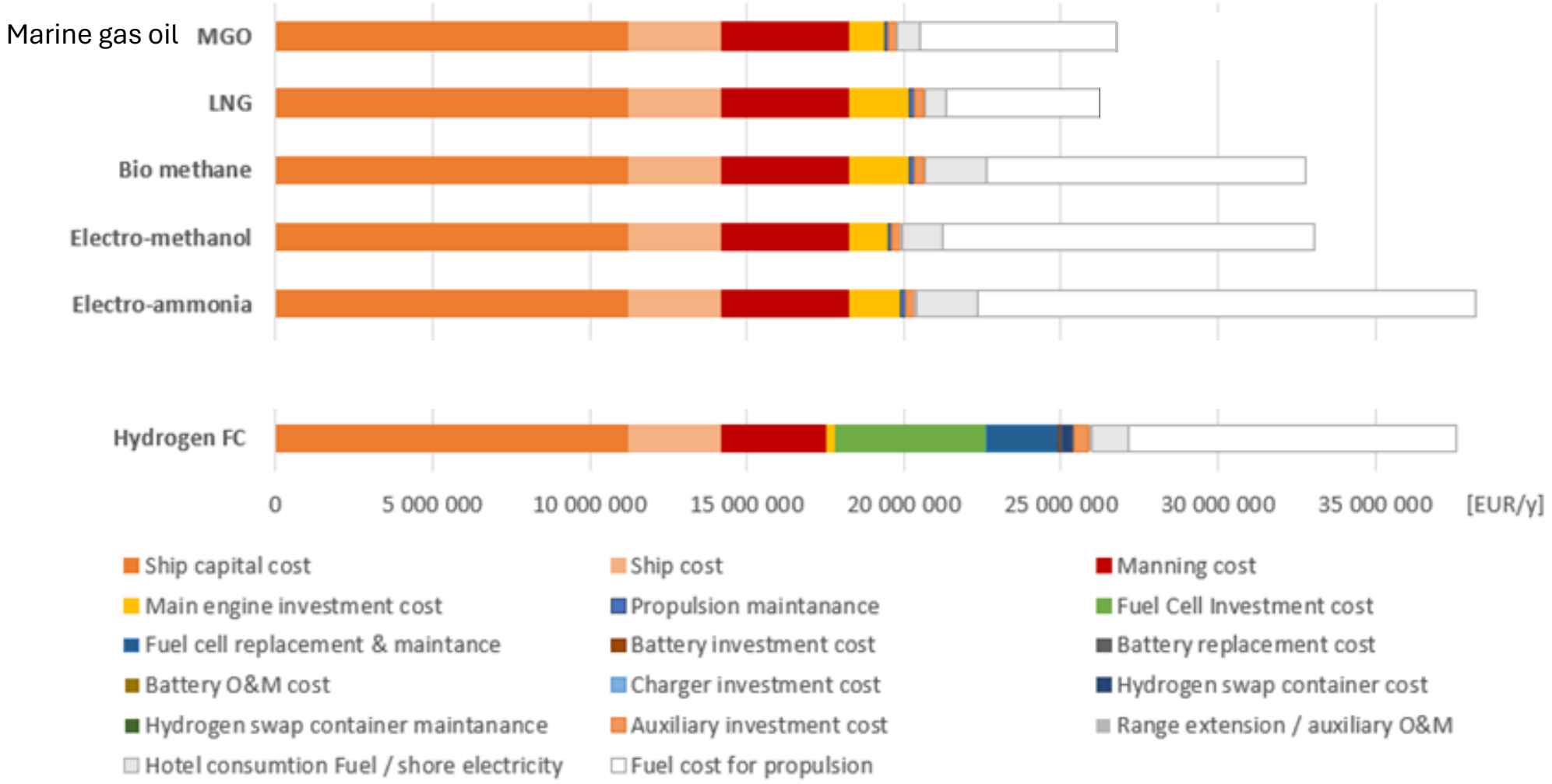




SINTEF

What about the possible cost for marine hydrogen based solutions?

Preliminary cost HOPE RoPax case study (to be updated)



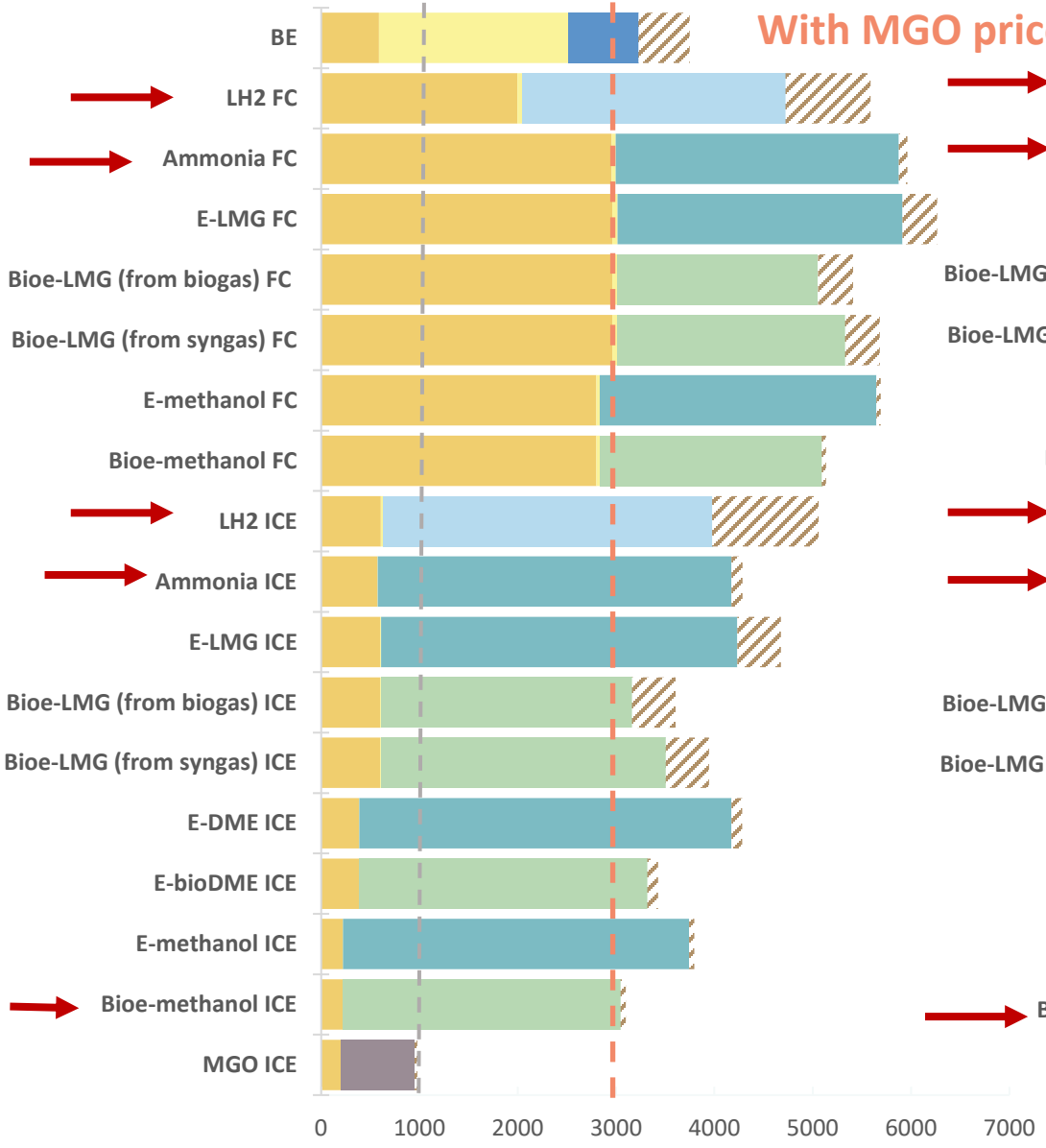
More cost comparisons for marine hydrogen based solutions

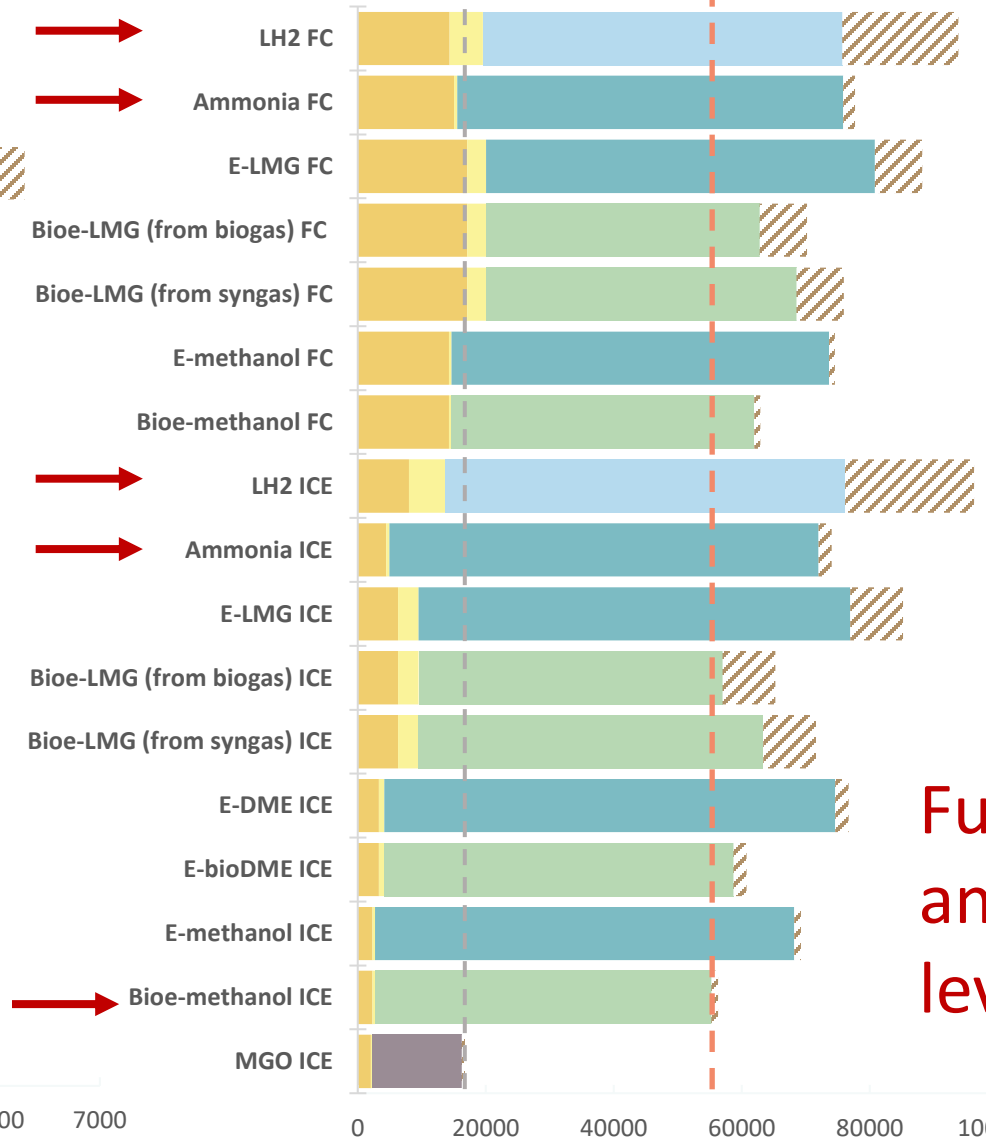
- Cost (2030) incl. fuel production, distribution + propulsion cost
- Large ferry & Container ship
- Fuels: Liquid hydrogen, ammonia, electrofuels, combined bio- and electrofuels
- Internal combustion engines (ICE), fuel cells (FC)

Large ferry

Container ship

With MGO price March 2022





BE: battery-electric, LH2: liquifed hydrogen, FC: fuel cell, ICE:internal combustion engine
LMG: liquifed methane gas; bioe: bioelectrofuel, formed by adding H2 into biofuel prod.

Source: Brynof el at., 2022

For the assessed ships:

- Bio-e-methanol in ICE lowest cost
- If H2/ammonia or fuel cell/ICE less costly depend on ship type
- Battery-electric propulsion also interesting for ferry

Future cost of fuels and EU ETS price levels important!

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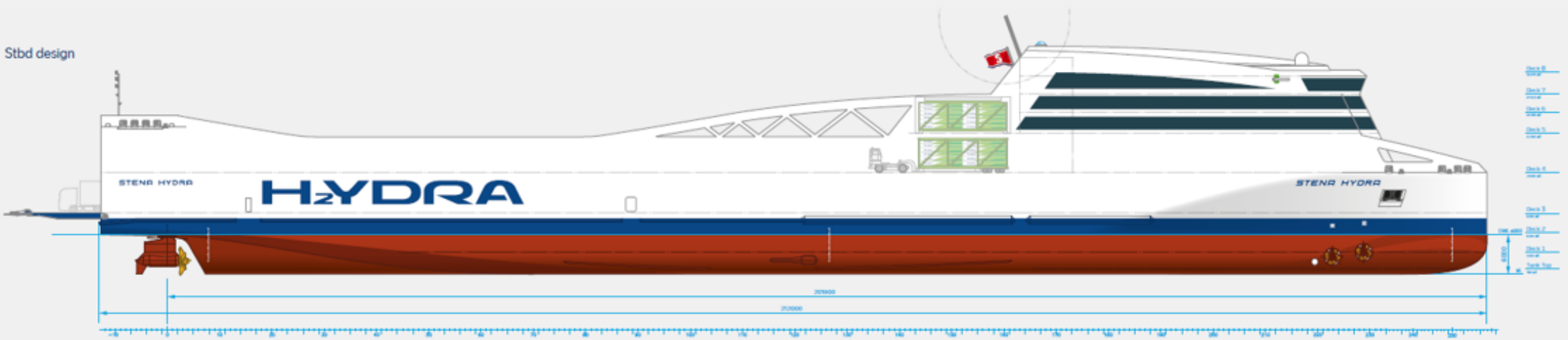
Is fuel cell RoPax feasible?



- Seems technically feasible
- Potentially economically feasible with right conditions
- Increased operational range compared to battery-electric vessels
- Business case will depend on several uncertain factors

Future role of hydrogen and electrofuels for shipping depends on

- development of hydrogen-based solutions (cost, emissions etc)
- GHG emission performance
- expansion of low-carbon electricity generation
- availability of sustainable (marine) biofuels
- hydrogen demand in other sectors
- cost development of electrified options
- development of carbon capture & storage/CCS and bio-CCS
- **policies and details in the design**

Potential impact on emissions of an introduction of hydrogen and fuel cell-based propulsion in Nordic shipping

Scenarios by 2030 and 2050

Estimation of Nordic fleet based on port call statistics, ships >5000 gross tonnage

Factors considered

- Transport development based on DNV (2020): High and low growth case
- Ship size, Energy efficiency improvements, Improved utilization

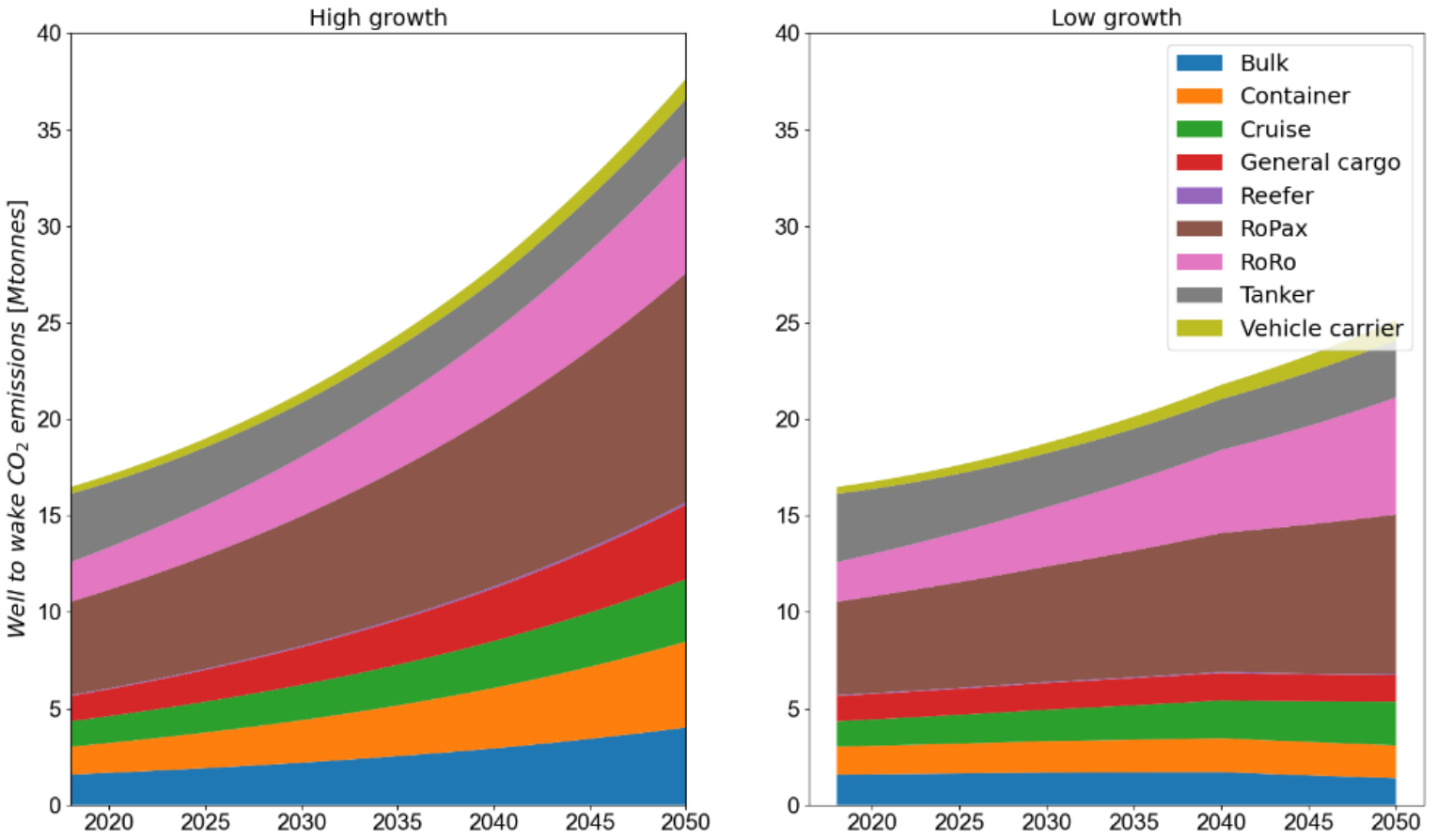
3 scenarios

- Scenario 1 – all ferries in and between the Nordic countries (Only Nordic ferries)
- Scenario 2 – all ships with voyages up to 600 NM (*Up to 600 NM are considered potentially possible for hydrogen and fuel cell propulsion as a rough estimate*)
- Scenario 3 – all ships all distances

Scenario 1+2: Potential emission reduction of CO2, NOx, particles in 2030/2050 due to intro of hydrogen in fuel cells

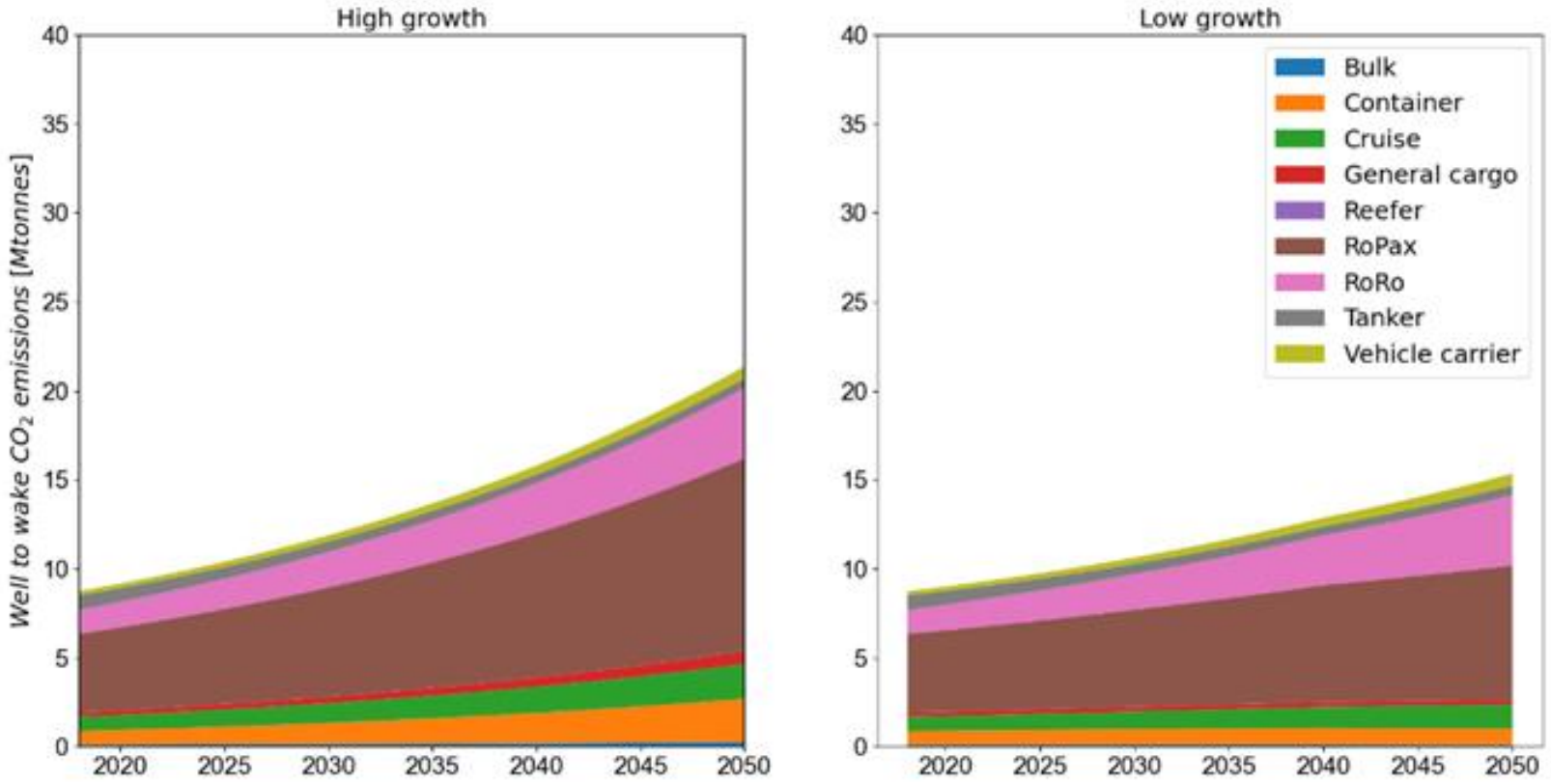
Growth	Year	Scenario 1 & 2	CO_{2eq} WTW (Mtonnes)	NO_x TTW (ktonnes)	PM TTW (ktonnes)
Low	2030	1. Only Nordic ferries	1.9	30	2.2
		2. All ships	8.2	143	11.6
	2050	1. Only Nordic ferries	2.6	18	3.1
		2. All ships	10.2	65	14.4
High	2030	1. Only Nordic ferries	2.1	34	2.5
		2. All ships	9.5	167	13.8
	2050	1. Only Nordic ferries	3.7	26	4.4
		2. All ships	17.1	109	25.2

Scenario 3: Well-to-wake CO2 emissions (2018-2050), no hydrogen (BAU)



*under the conditions of business as usual, i.e., no introduction of alternative fuels

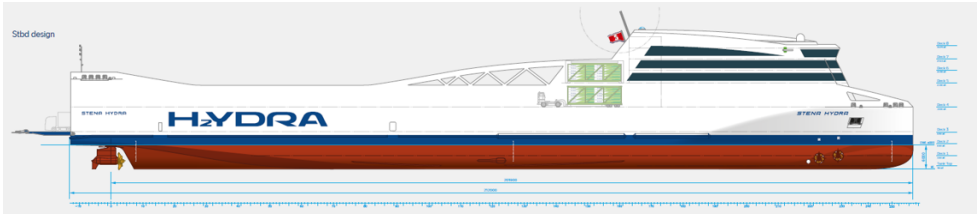
Scenario 3: Well-to-wake CO2 emissions (2018-2050), hydrogen introduction



Scenario 2 results represented by RoPax category

Some more findings from HOPE

- It seems possible *from a technical perspective to use hydrogen for a regional RORO-ROPAX vessel*, between the Nordic countries, even if electrification has advantages on certain routes.
- Hydrogen-based solutions for shipping is *not the lowest cost option for regional shipping*. Problems also for other options.
- *Primarily economic barriers* e.g., high costs, uncertainty and high risk.
- Availability of hydrogen/electrofuels for shipping uncertain
- Possible to substantially reduce GHG emission by introducing hydrogen-based options by 2030 (2050 even more). Other air pollution emission will decrease too!



Interested in more? Check our publications

“HOPE Hydrogen fuel cells solutions in NORDIC shipping. Project summary”, Hansson, J., Jivén, K., Yum Koosup, K., et al., 2023, https://www.ivl.se/projektwebbar/hope.html

“Concept design and environmental analysis of a fuel cell RoPax vessel”, Jivén, K., Parsmo, R., Fridell, E., J., et al., 2023, Report C781, IVL, https://www.ivl.se/projektwebbar/hope.html

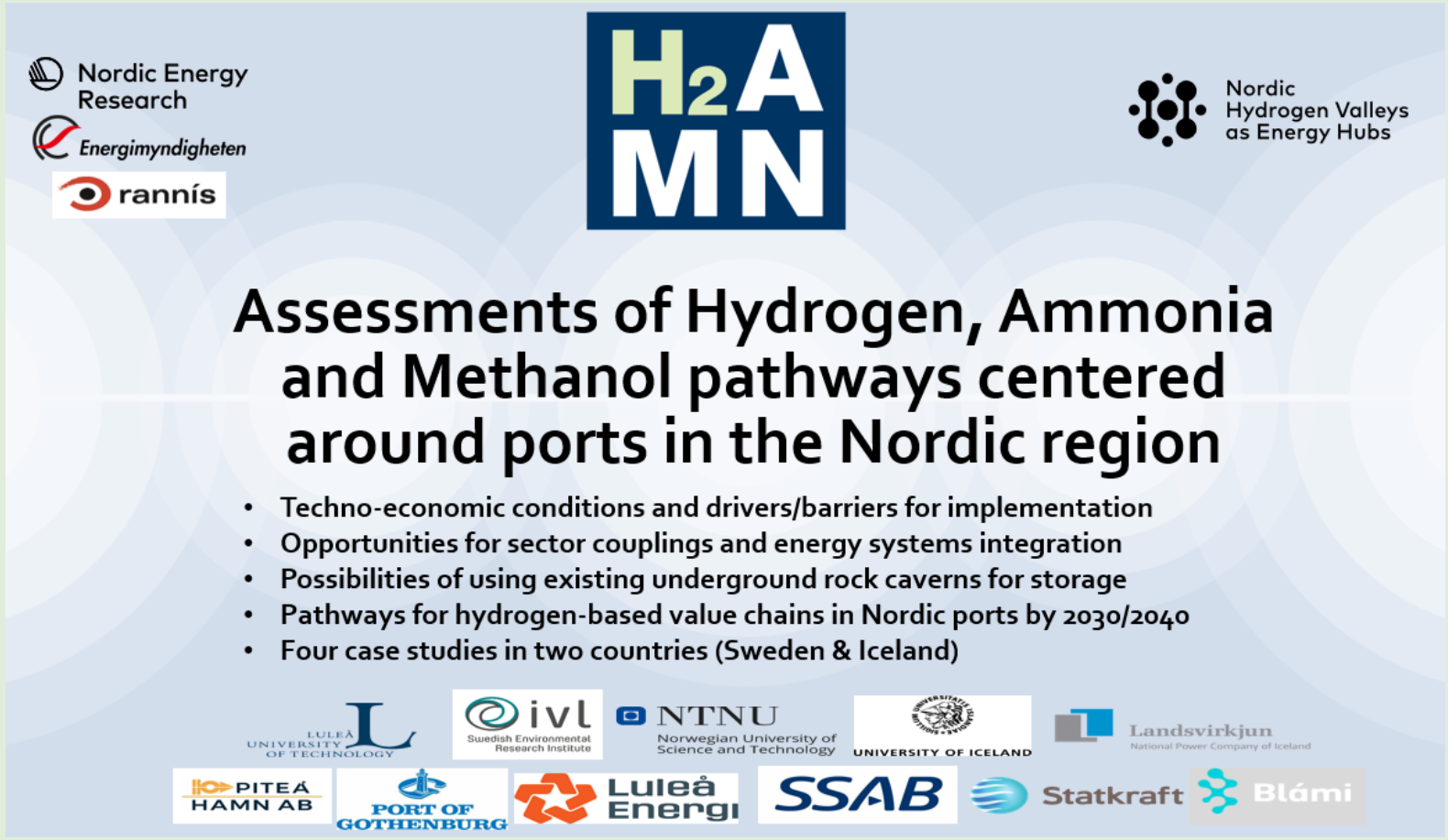
“Life-Cycle Assessment and Costing of Fuels and Propulsion Systems in Future Fossil-Free Shipping”, Kanchiralla, F.M., Brynolf, S., Malmgren E., Hansson, J., Grahn, M., *Environmental Science & Technology* 56 (17), 2022

"**Review of electrofuel feasibility - Prospects for road, ocean and air transport**", Brynolf, S., Hansson, J., Anderson, J., et al., *Progress in Energy* (4) 042007, 2022

"**Review of electrofuel feasibility - Cost and environmental impact**", Grahn, M., Malmgren, E., Korberg, A., et al., *Progress in Energy* (4) 032010, 2022

“How do variations in ship operation impact the techno-economic feasibility and the environmental performance of fossil-free fuels? A life cycle study”, Kanchiralla, F.M., Brynolf, S., Olsson, T., et al., *Applied Energy* 350, 2023

“**Life Cycle Assessment of Marine Fuels in the Nordic Region – Task 1C Roadmap for the introduction of sustainable zero-carbon fuels in the Nordic region**”, Brynolf, S., Hansson, J., Kanchiralla, F.M., et al., Report No.1-C/1/2022, 2022, https://futurefuelsnordic.com/project-deliverables/



Thank you! julia.hansson@ivl.se

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