Ammonia & maritime decarbonization

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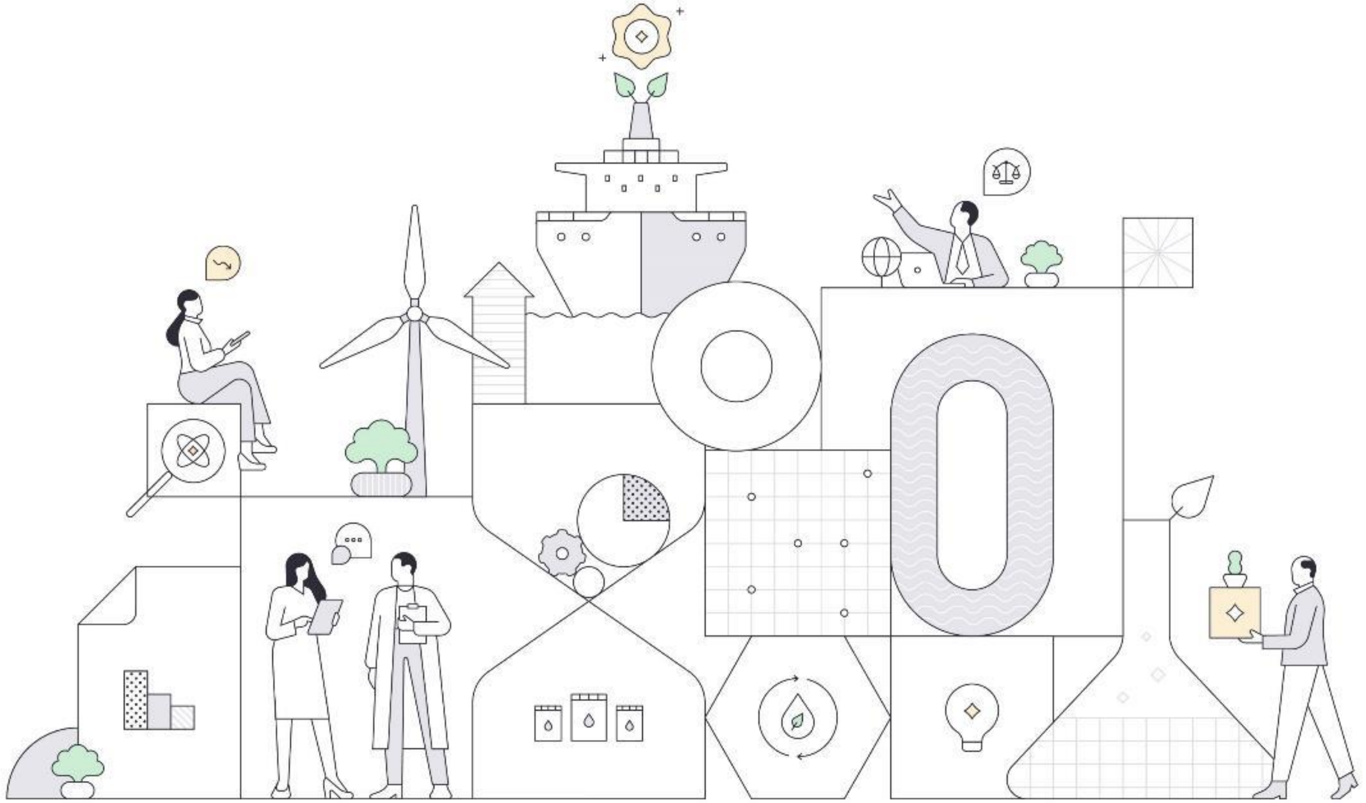

Mærsk Mc-Kinney Møller Center
for Zero Carbon Shipping

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Founded in **2020** with initial base funding of **DKK 400mn** (approx. US$ 64 mn) by A.P. Møller Foundation

Located in **Copenhagen: a central team** with a **global** outreach

Registered as a **not-for-profit commercial foundation with a charitable purpose.** Self owned entity.

Neutral and open platform for collaboration across the value chain, with an anticipated **growing partnership base**

Established by seven founding partners from across the ship-powering supply chain, with commitment to contribute resources

ABS MAERSK MITSUBISHI HEAVY INDUSTRIES, LTD. SIEMENS

Cargill MAN Energy Solutions NYK LINE

Our Guiding Principles

- We are independent and neutral, aiming for objectivity through transparency, facts and scientific methods
- We are open-minded to and unbiased about new ideas
- We enable and inspire leadership for the industry
- We believe in partnering and collaboration
- We are tenacious due to our sense of urgency
- We build confidence and trust
- We show the world it is possible – and *how*

Many industry projections – clarity of transformation path(s) needed

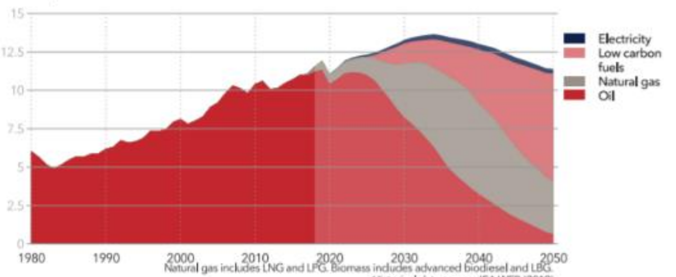
DNV GL Energy Transition Outlook

60% Low carbon fuels / 30% LNG / 10% Fuel Oil

FIGURE 1.10

World maritime subsector energy demand by carrier

Units: EJ/yr



Natural gas includes LNG and LPG. Biomass includes advanced biodiesel and LBG.
Historical data source: IEA WEB (2019)

ABS sustainability Outlook

40% Fuel Oil / 10% LNG / 35% Ammonia+ H2 /

7% Biofuels / 7% Methanol

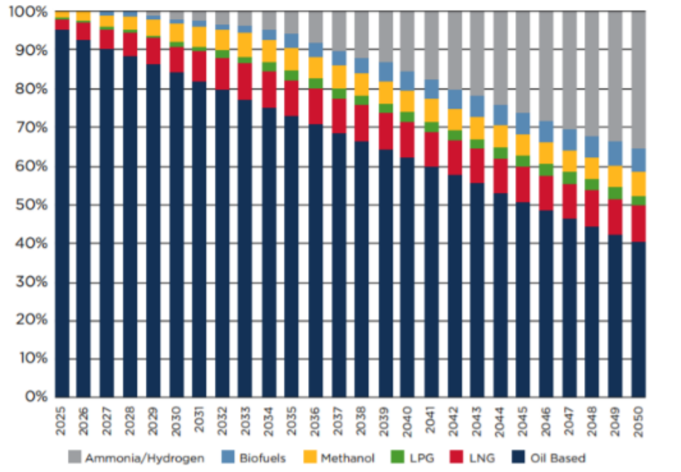


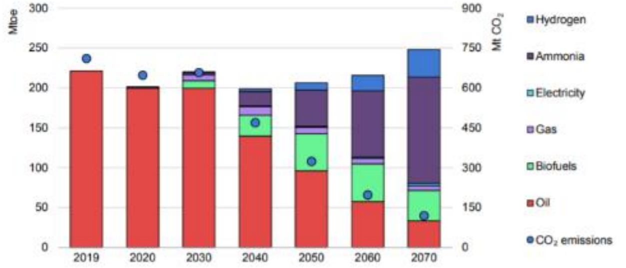
Figure 24: Projected marine fuel use to 2050

IEA

50% Fuel Oil / 25% Ammonia + H2 / 20% Biofuels

(Total consumption 210 MTOE)

Figure 5.11 Global energy consumption and CO_2 emissions in international shipping in the Sustainable Development Scenario, 2019-70



Notes: Efficiency improvements more than offset activity growth in the 2030s and 2040s, but by 2050 activity demand growth overwhelms efficiency improvements, leading to increases in final energy demand. The category biofuels includes biomethane and is considered to be carbon neutral.

Emissions from international shipping fall by more than four-fifths between 2019 and 2070 in the Sustainable Development Scenario, mainly due to switching to biofuels and hydrogen-based fuels.

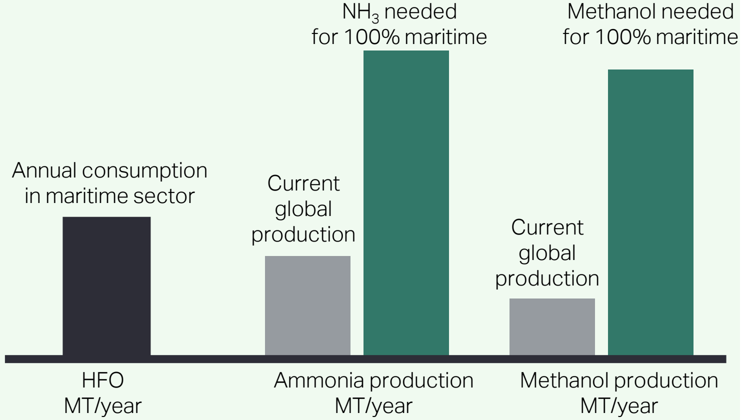
The scope of the challenge of maritime decarbonization

Complexity

- A global industry
- Approx. 70,000 vessels
- Long lifetime of assets
- Hard-to-abate sector

Scale

- Replace +250 million ton HFO/year
- Massive scale-up of renewable power and green fuel production
- Growth of infrastructure; bunkering



Technical feasibility: P2X2P

- Maturation and implementation of new end-to-end systems
- On-shore: From feedstock to "X"
- Vessels: Energy conversion, efficiency and emissions.
- Safety & regulation

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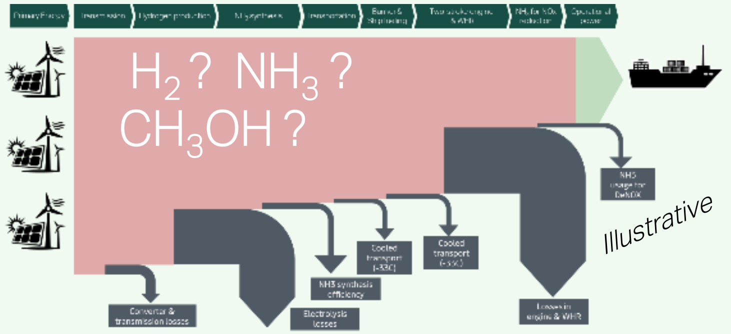
Net-zero pathways & the role of the new center

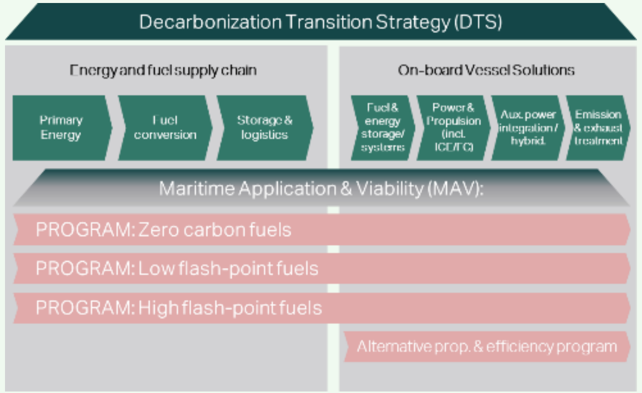
End-to-end efficiency is key

- Indirect electrification →
- Impact of the choice of "X"
- Reduces losses in the chain
- Reduce CAPEX in all process steps



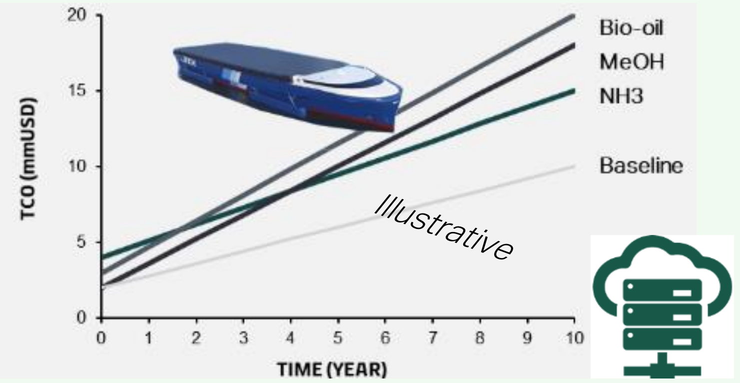
The role of the new center…

- Structured R&D: Clarity & overview
- Comparison of possible future solutions using consistent frameworks, data and methods,



… to accelerate a transition

- Commercial viability vs. status quo
- Create level playing field
- Regulatory framework and financial instruments



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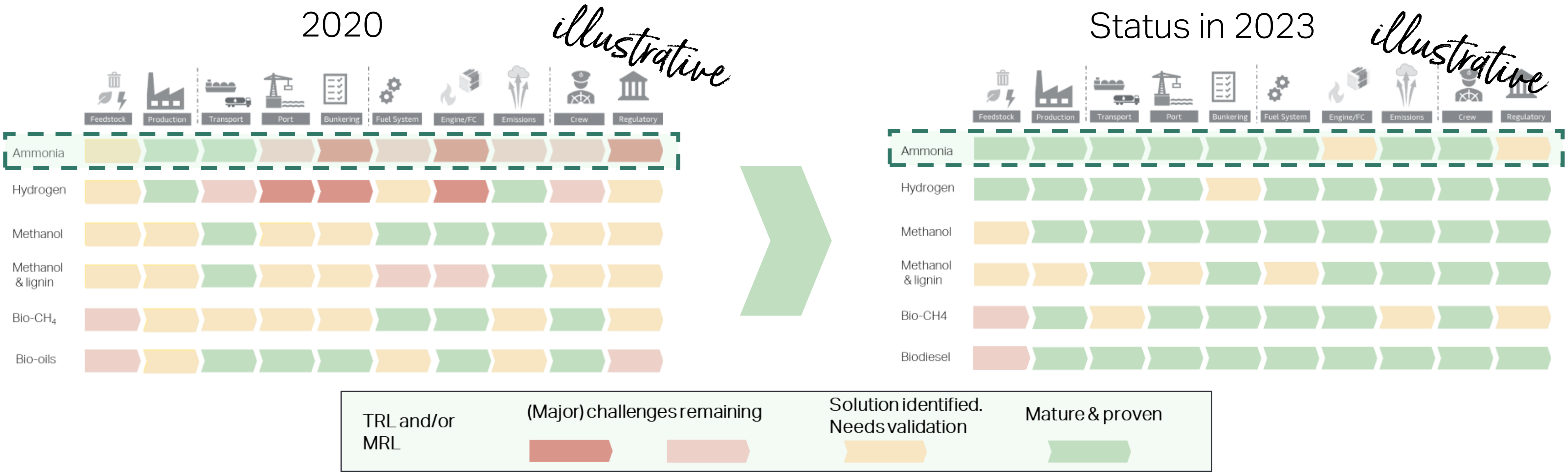
We apply a structured approach to technical- and commercial feasibility assessments

The Center will create overviews and be involved in a portfolio of R&D- and demonstration projects to de-risk pathways with development needs for each vessel segment.



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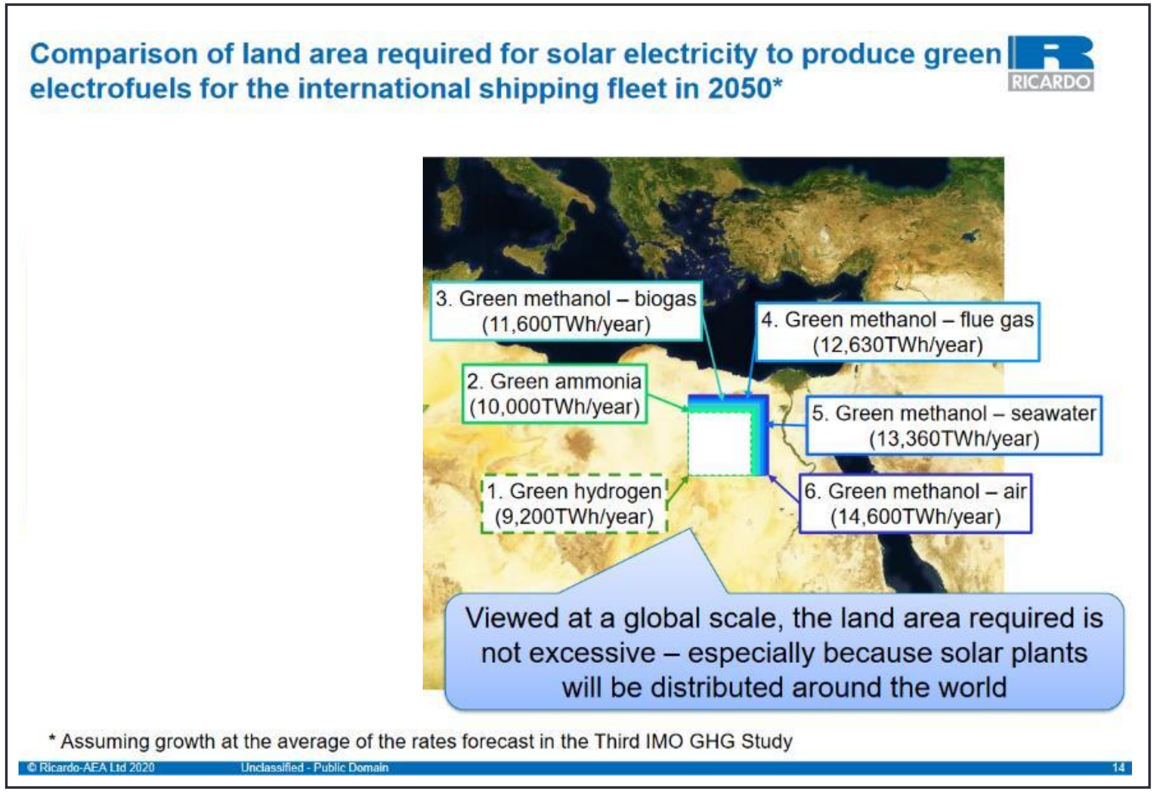
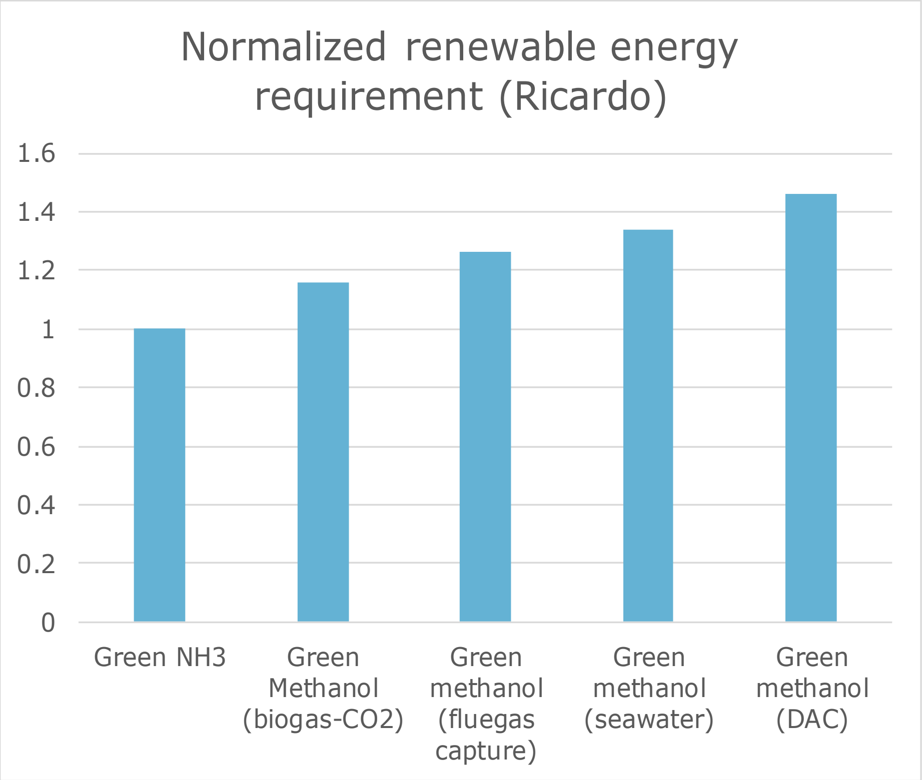
Estimation from Ricardo: eFuels for shipping by 2050





- Cost of CO_2 (= energy for capture) is critical for the methanol pathway
- Co-location of H_2 and biogenic CO_2 ?
- Long-distance transport of 'hydrogen energy' is more feasible as ammonia(*)

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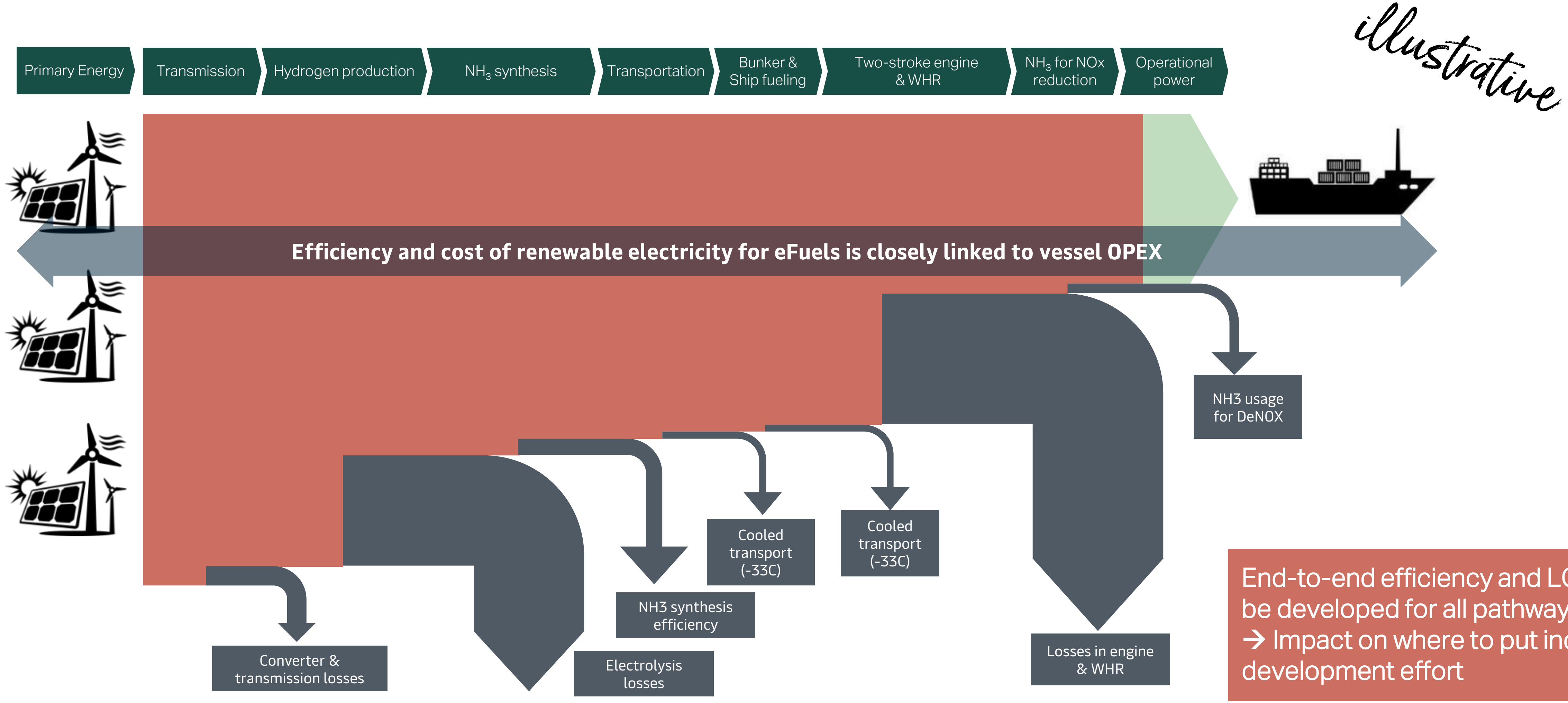
(*) https://royalsociety.org/-/media/policy/projects/green-ammonia/green-ammonia-policy-briefing.pdf

Top-down overview to facilitate R&D focus

Cost, losses, decarbonization potential, life-cycle-analysis, safety, TRL

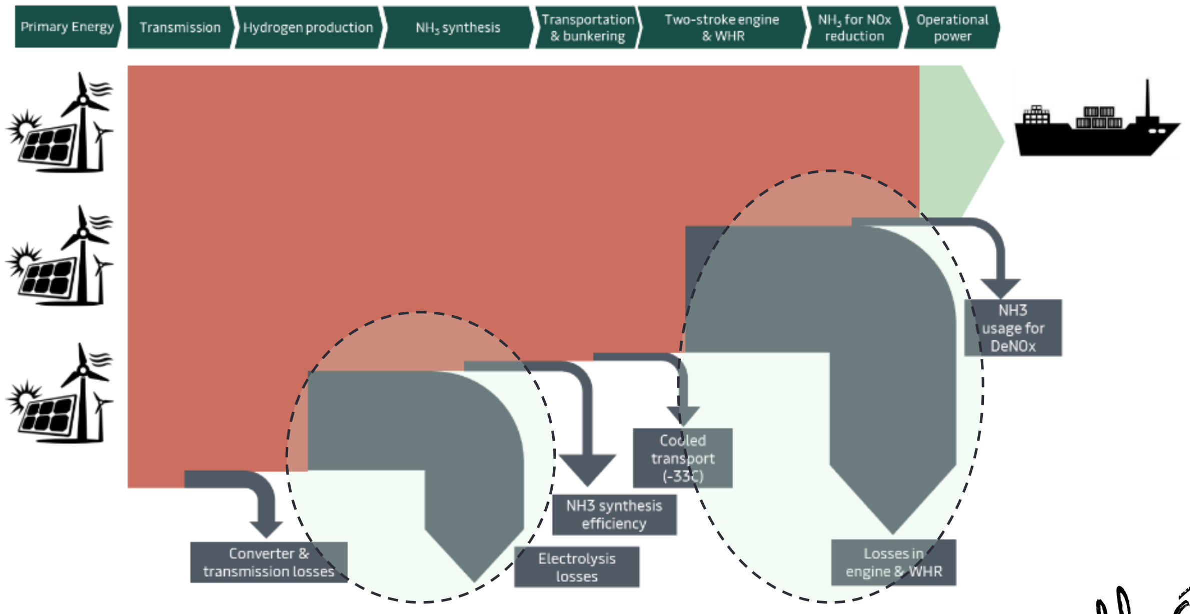


End-to-end efficiency and LCA to be developed for all pathways
→ Impact on where to put industry development effort

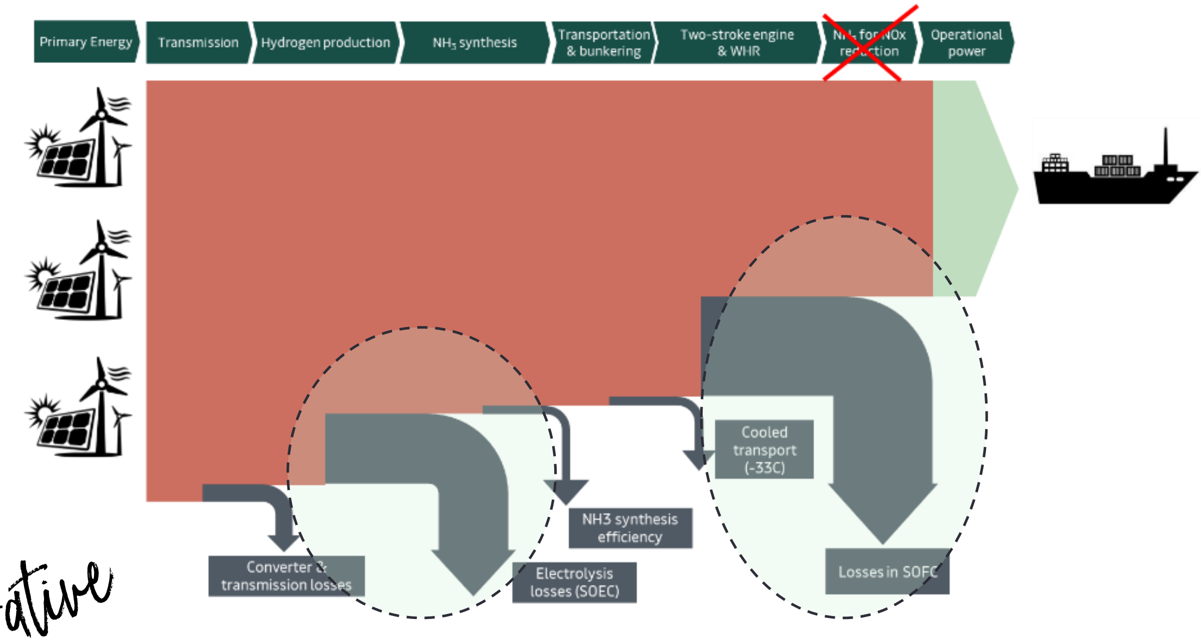
For same Power-to-X-to-Power path:

Example of individual links in the chain contributing with significant end-to-end impact.

Low-temperature electrolysis and ICE

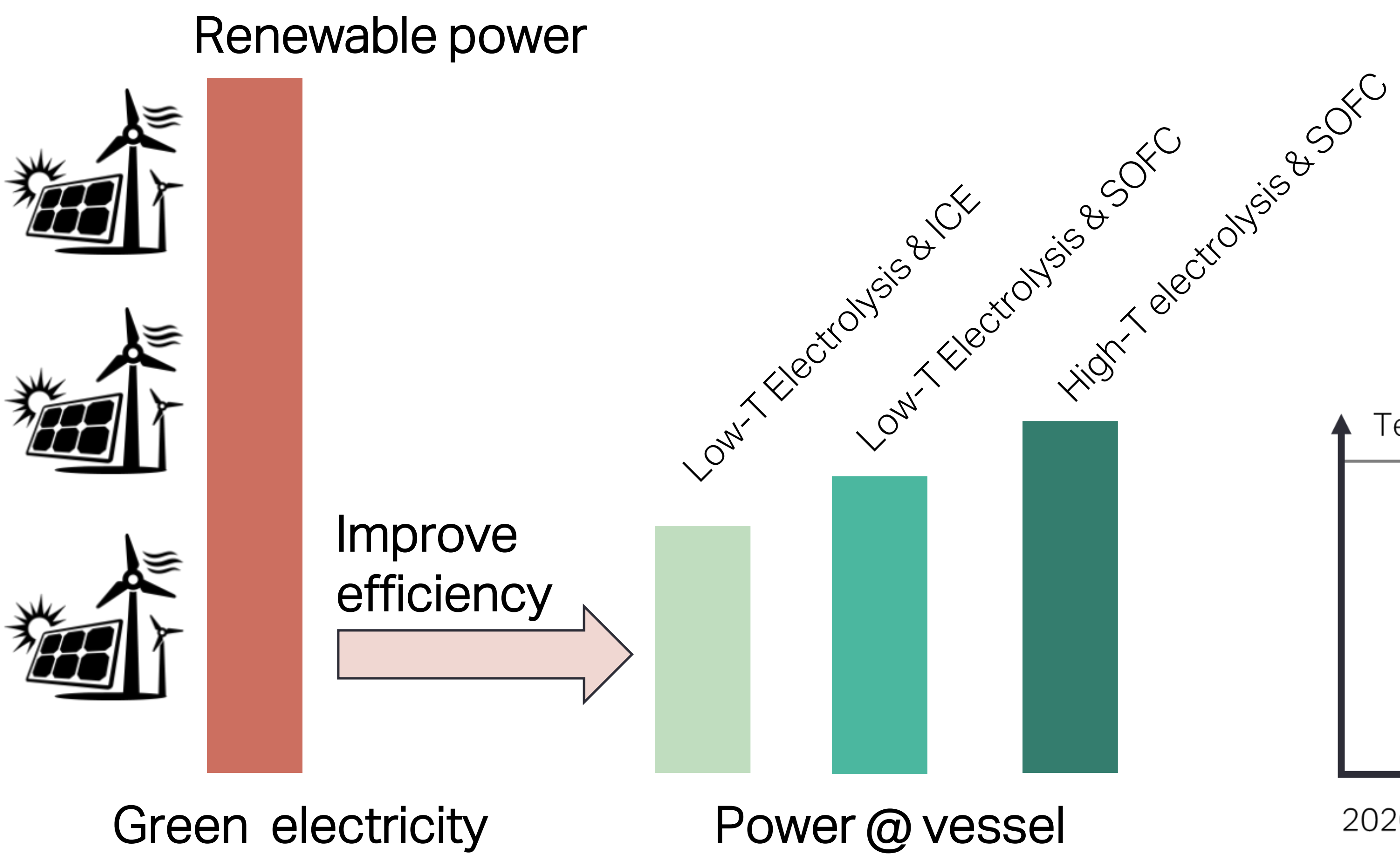


Example: High-temperature electrolysis and SOFC



illustrative

With future technology “bricks”, we could approach 45% RTE



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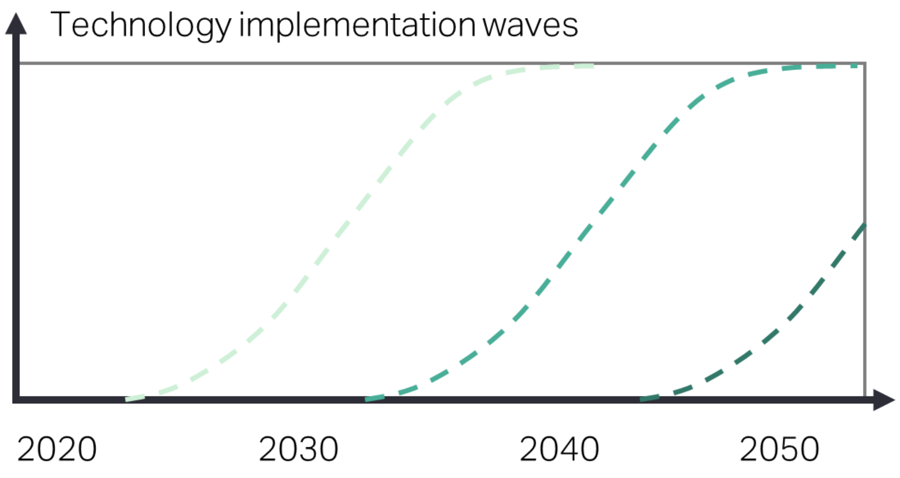

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Thank you for your attention

A 10% improvement in “wind-to-wake” efficiency can reduce by ~20,000 the number of 10 MW off-shore wind turbines required for maritime P2X

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