Decarbonisation pathways for the shipping sector

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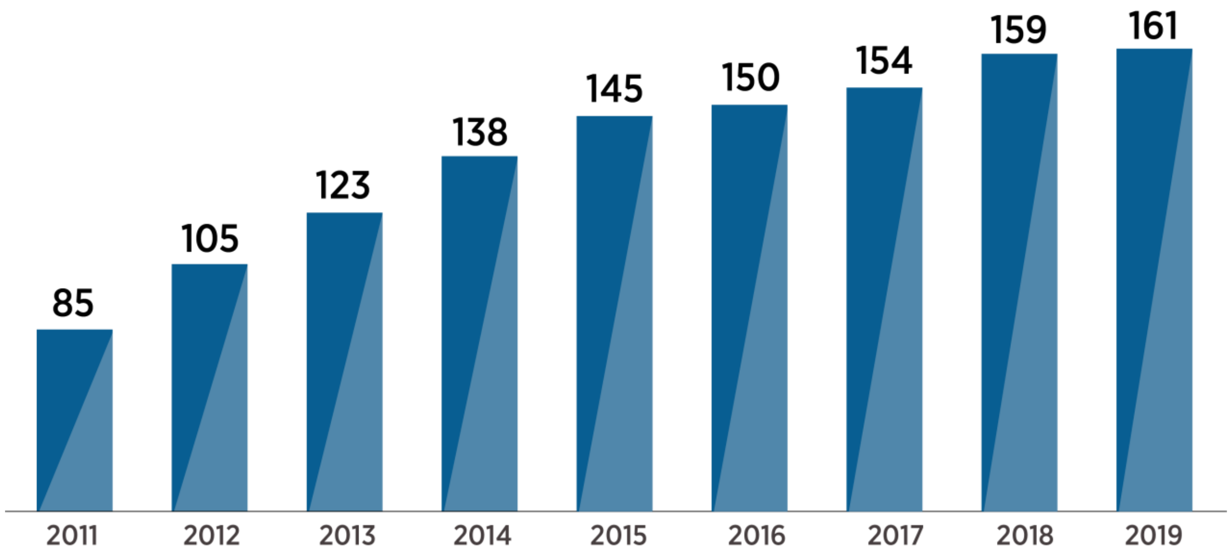
Prospects for energy and maritime transport in the Nordic region
Malmö, 26-27 February 2020

IRENA at a glance

- Intergovernmental Organization (IGO)
- Established in 2011
- HQ in Abu Dhabi, UAE
- IRENA Innovation and Technology Centre – Bonn, Germany
- Permanent Observer to the United Nations
- Director-General – Francesco la Camera



Membership

161 members + 22 in accession

Important considerations in the context of shipping

- **Similarities with power sector**
  - Long-lived assets, high upfront capital costs
  - Could likely benefit from technology-specific support mechanisms to reduce costs

- **Differences with power sector**
  - Shipping sector competes internationally
  - Shipping is outside national climate policy regimes
  - Different techno-economic challenges
    - RE: capital costs, variability
    - Shipping: fuel costs and availability

Let's start with the problem

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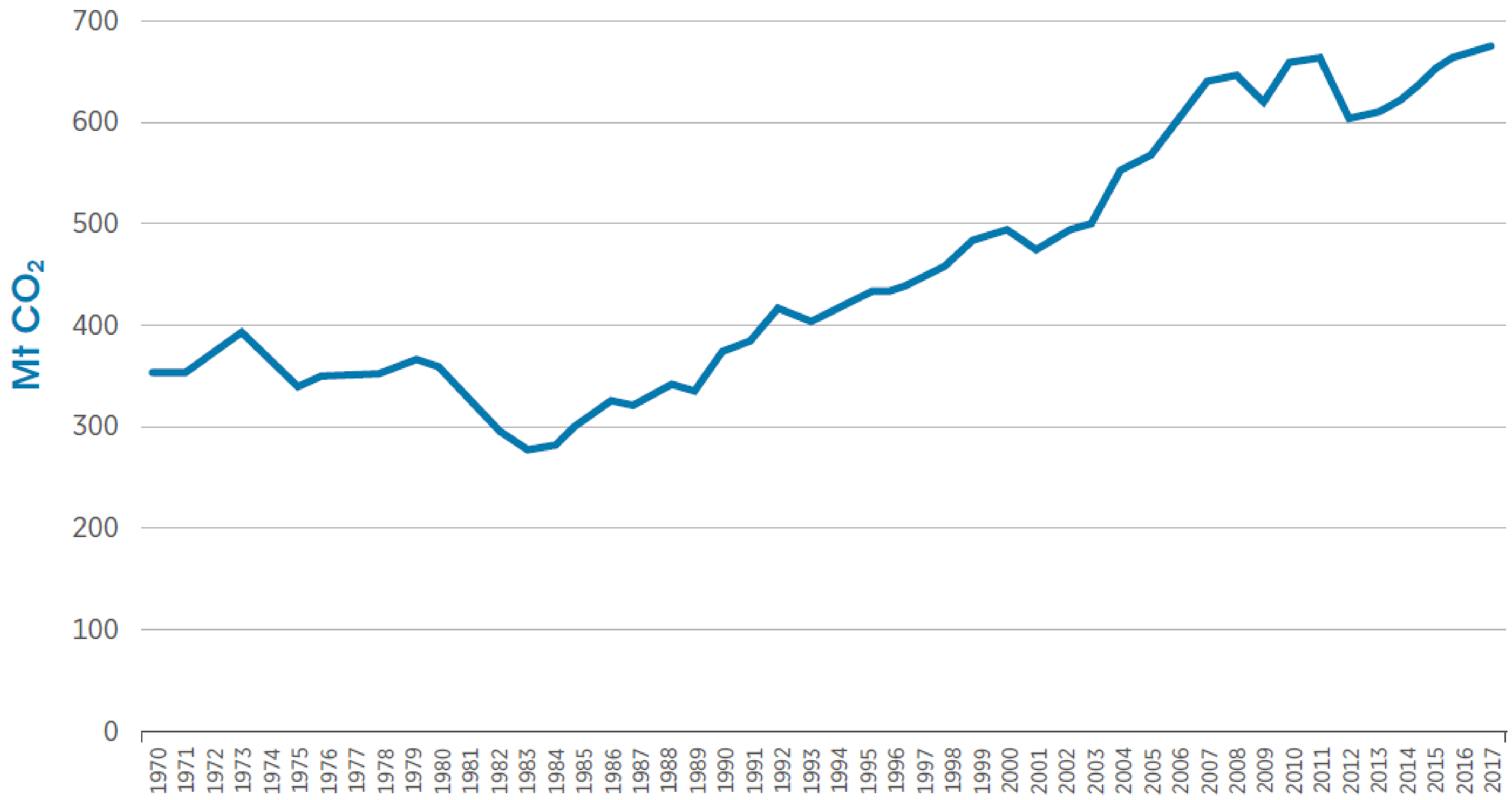
On average, the shipping sector is responsible for 3% of annual global green-house gas emissions on a CO2-equivalent basis.

Annual CO2 emissions associated with international shipping



Source: JRC-EDGAR (2018)

What are the options?

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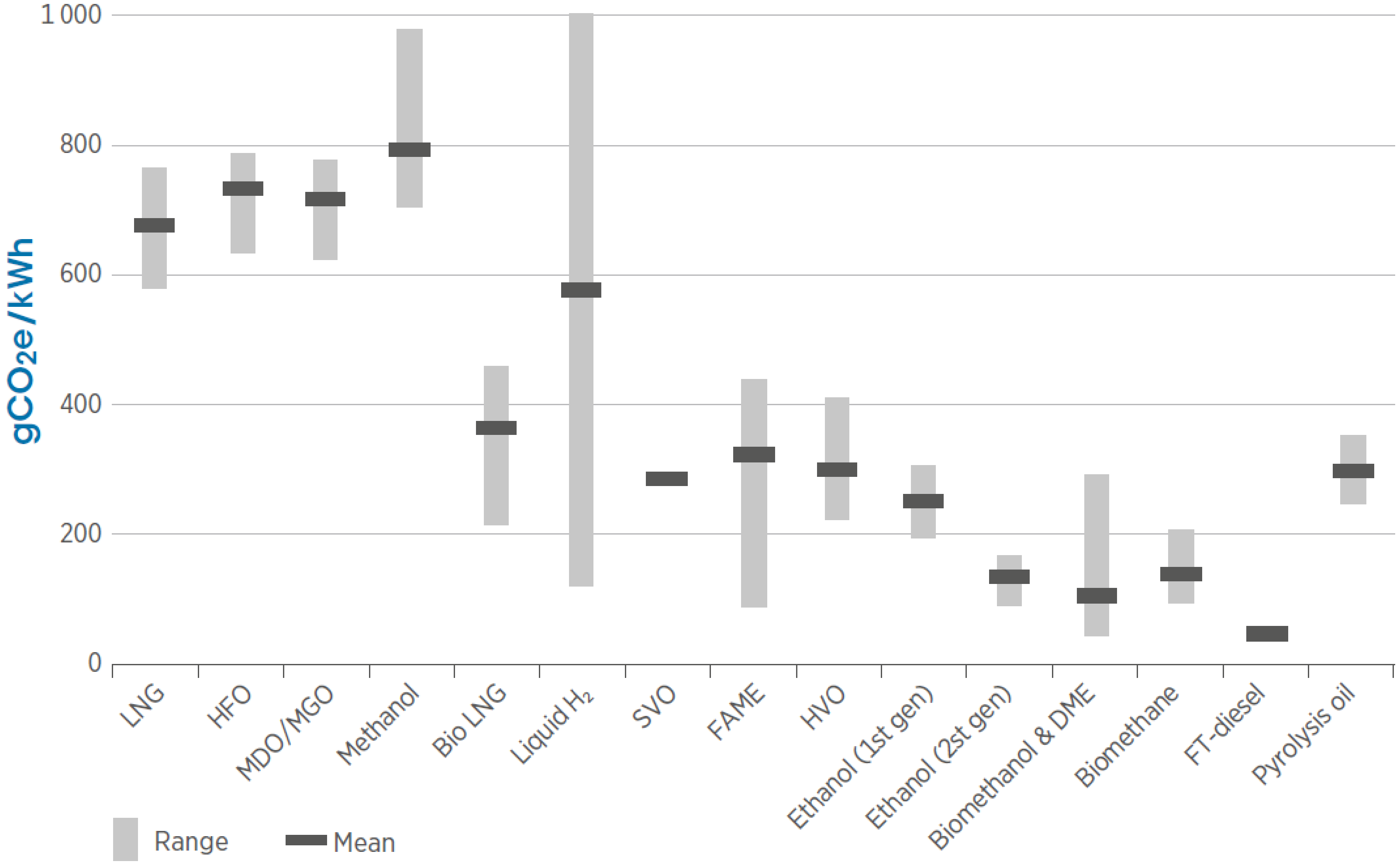
- Alternative marine fuels / propulsion
  - Biofuels
    - Biodiesel substitutes
    - Bio-alcohols
    - Gaseous biofuels
  - E-fuels
    - Hydrogen
    - Ammonia
    - Methanol
    - Methane
    - Other liquid fuels (gasoline, diesel)
- Electric engines / Batteries
- Efficiency improvements
  - Incl. solar and wind applications
- Other technologies (carbon capture)

Not all fuels are made the same

Total life cycle GHG emissions per kWh of engine output for different fuels



Source: Balcombe et al. (2019)

Biofuels

+ GHG, NOx and SOx emission reductions

+ Some are compatible as drop-in fuels

+ Safer in case of spills due to biodegradability

+ Low storage, bunkering, infrastructure and logistics costs (diesel substitutes)

- Can reduce engine lifespan (carbon build-ups, SVO; water contamination, FAME)

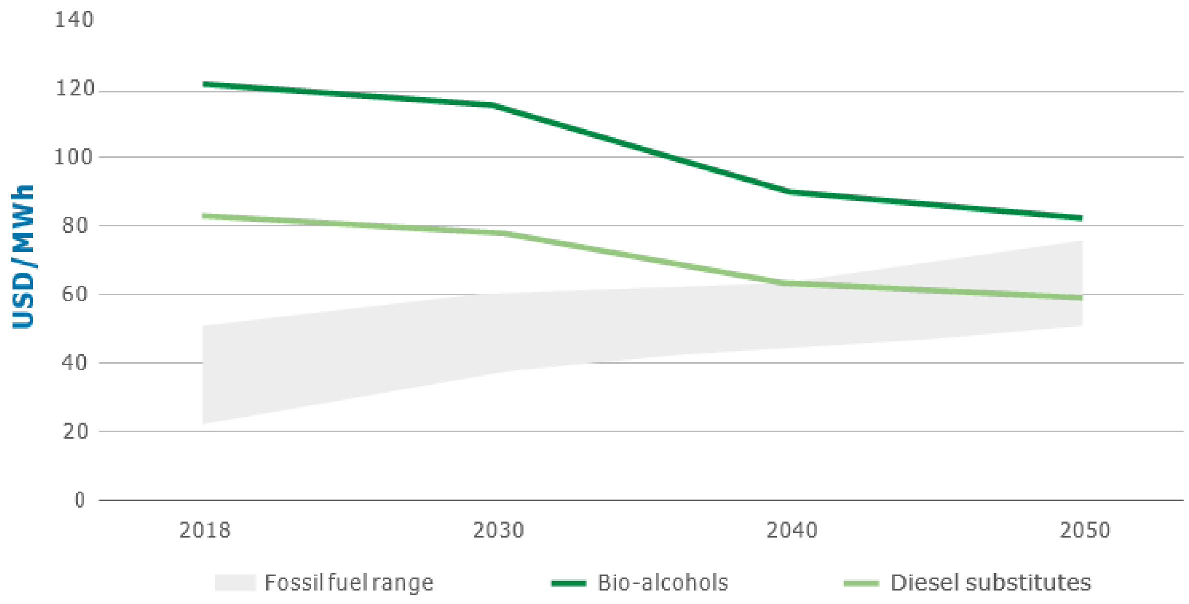
- Sustainability concerns

- Availability concerns

- High production costs (mainly due to feedstock)

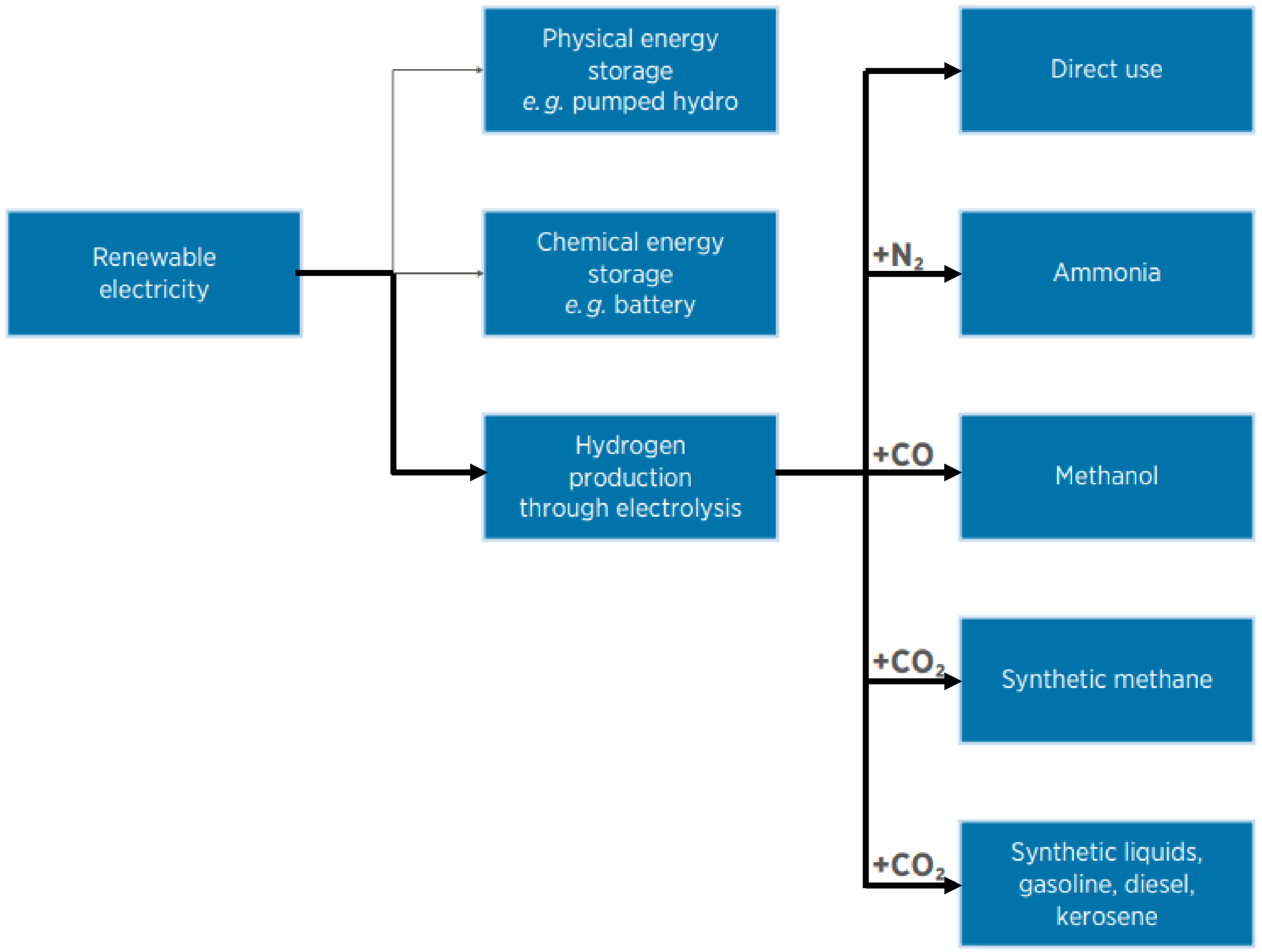
- High adaptation costs (bio-alcohols and gaseous biofuels)

Biofuel cost projections



Source: Biofuel cost projections (IRENA, 2016); fossil fuel cost range (Lloyd's Register, 2019; Ship & Bunker, 2019)

Power-to-X / E-fuels



Renewables are getting cheaper

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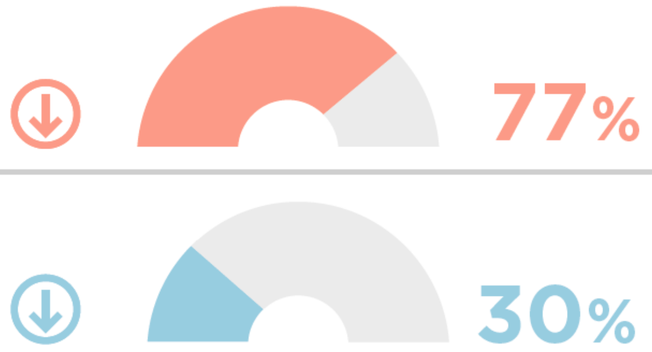
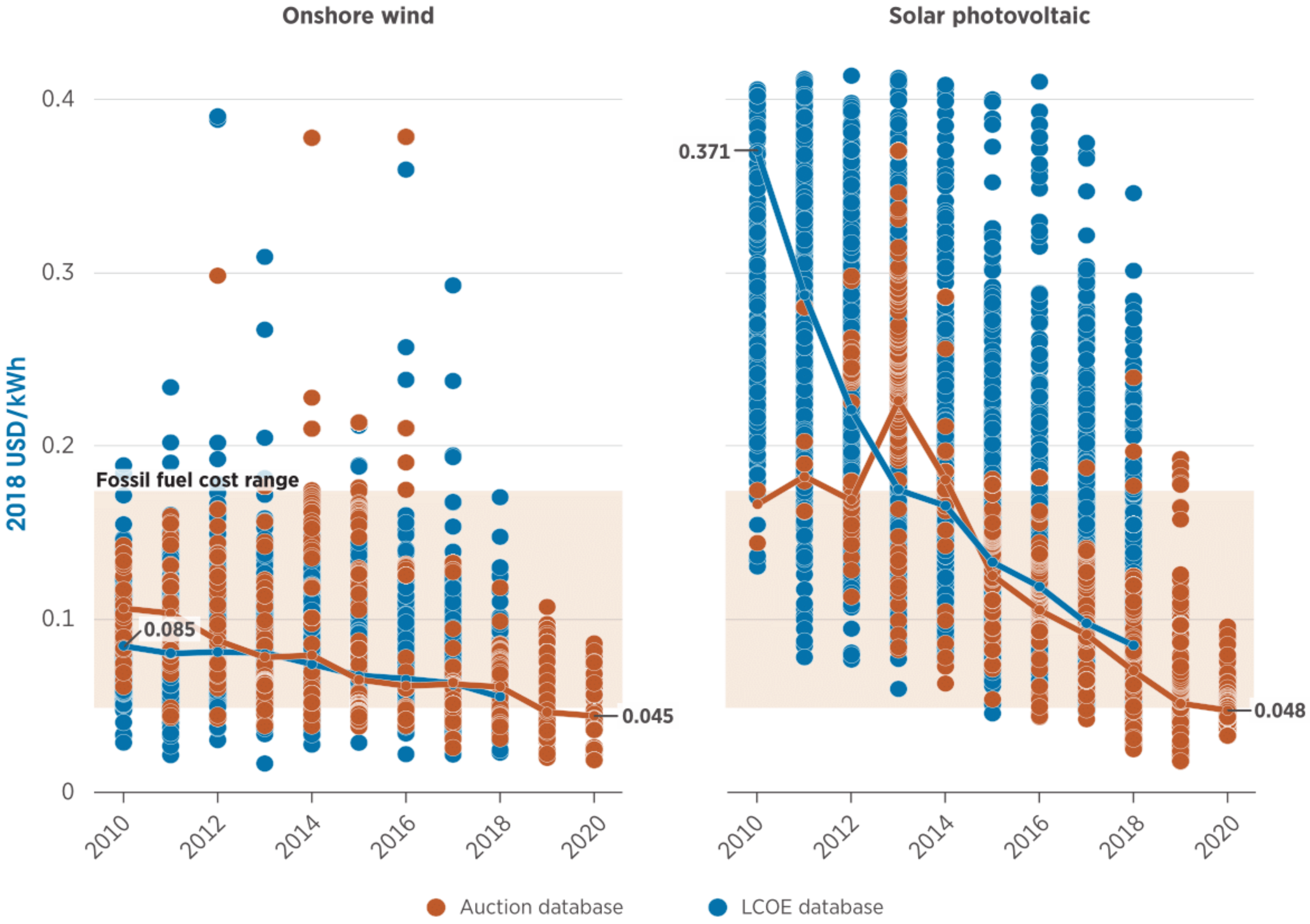
Cost reduction (2010 - 2018)

Solar PV



Onshore Wind



Hydrogen

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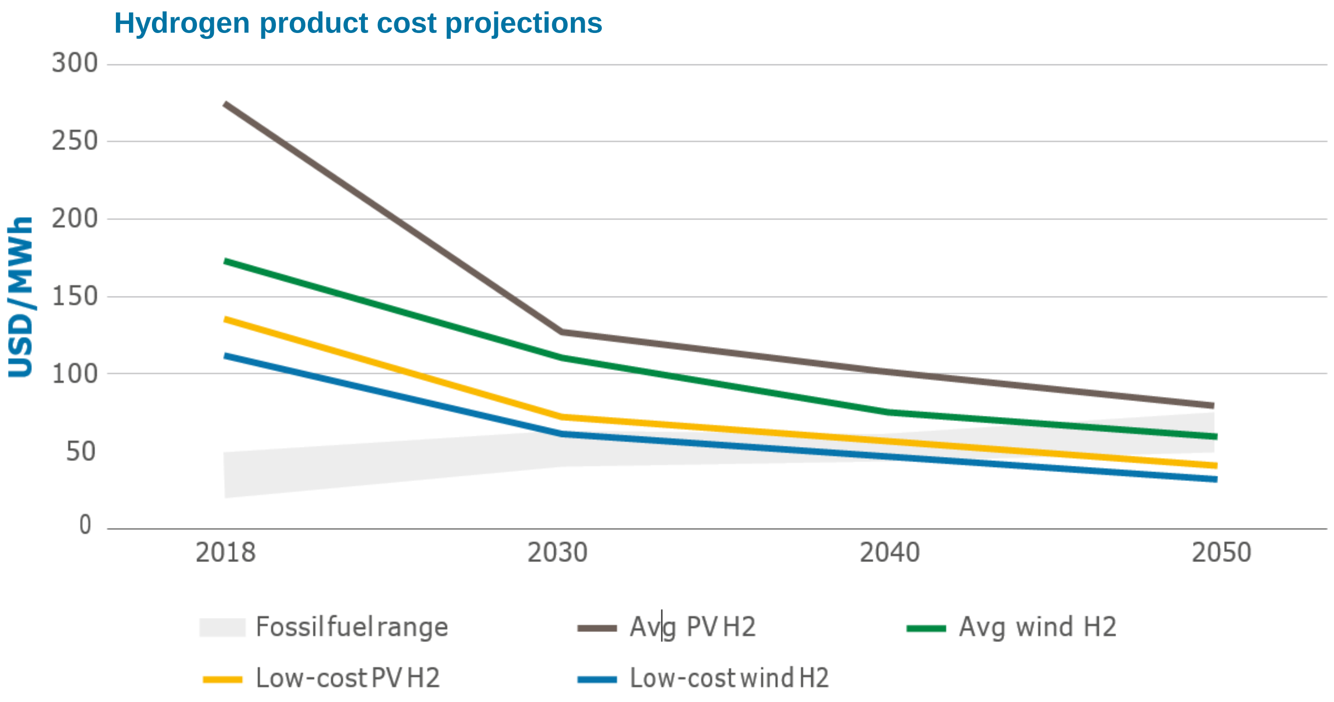
+ Zero carbon if produced from RES
+ No SOx and negligible NOx emissions

- Not at commercial scale
- Very low volumetric energy density
- Difficult to store, requires cryogenic temperatures or very high pressure
- Considerable changes to infrastructure and logistics
- High costs
- High flammability

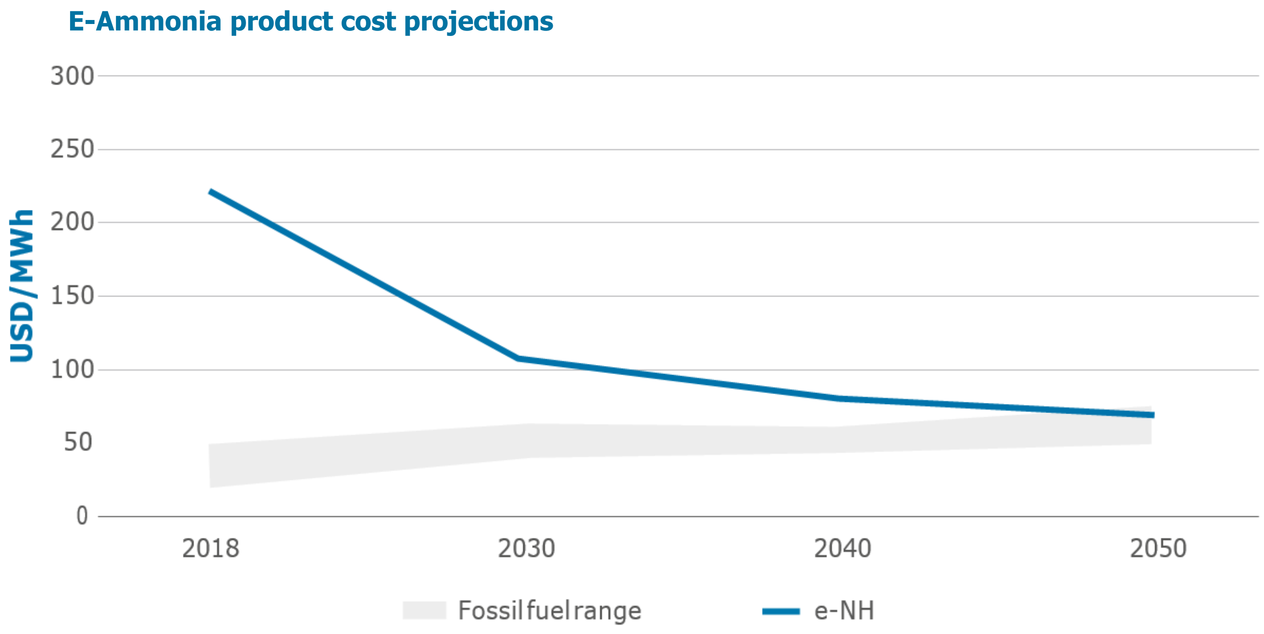


Source: Hydrogen cost projections (IRENA, 2019); fuel cost projections (Lloyd's Register, 2019; Ship & Bunker, 2019)

Ammonia

+ Zero carbon, SOx, and negligible NOx if used in fuel cells (can produce NOx if combusted, might need SCR)
+ Higher volumetric energy density than H_2
+ Easier to store than H_2
+ Widely used commodity

- No active commercial applications
- Bunkering and storage need modification due to refrigeration needs
- High costs
- Toxic



Source: Hydrogen cost projections (IRENA, 2019); fuel cost projections (Lloyd's Register, 2019; Ship & Bunker, 2019)

Overview and Outlook

- To achieve the 2050 carbon reduction targets, the shipping sector will need to shift to carbon-free propulsion alternatives such as advanced biofuels, electric propulsion, renewable hydrogen and other hydrogen-based fuels such as ammonia.

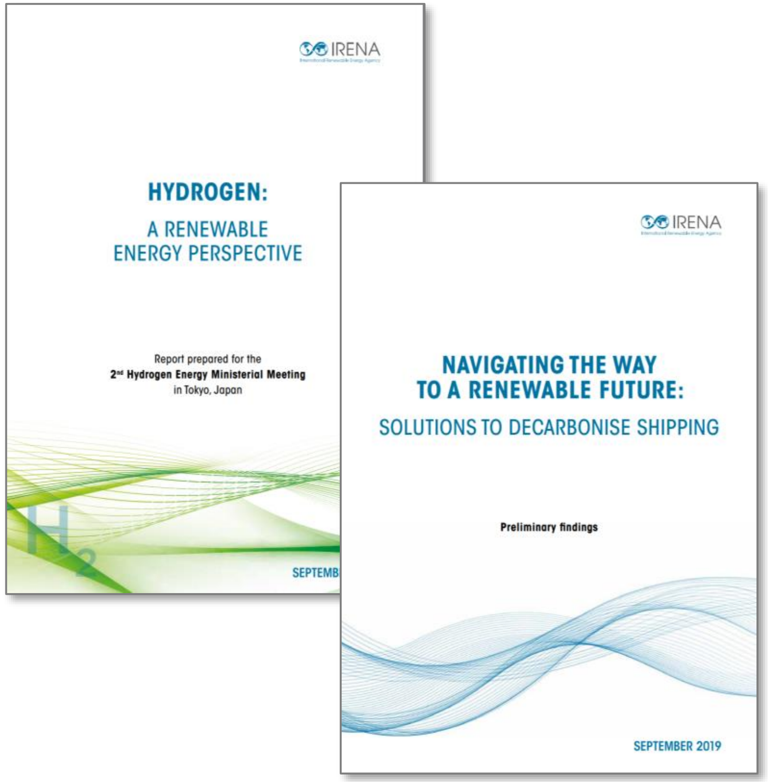
- Given that bunker costs can account for 24 - 41% of total vessel operation costs, fuel prices and its availability will play a critical role in selecting one or another clean fuel option.

- Other key, decisive factors will include the infrastructural adaptation costs of ships and ports, technological maturity and sustainability issues (e.g. food security in the case of biofuels).

- As the adoption of clean technologies grows across sectors, technology improves, renewable fuel costs fall and regulation becomes more favourable, carbon-neutral options are expected to become more competitive in the medium to long-term.

- Decarbonising the shipping sector will require a global effort where the close cooperation between private and public stakeholders will be highly important.

IRENA's work on Hydrogen and Shipping



https://www.irena.org/publications/2019/Sep/Hydrogen-A-renewable-energy-perspective

https://www.irena.org/publications/2019/Sep/Navigating-the-way-to-a-renewable-future

- **Key Findings - Hydrogen**
  - Important synergies with RE – Storage and flexibility
  - Electrolysers are scaling up from MW to GW
  - Electrolyser costs to halve by 2050 (850 USD/kW today)
- **Key Findings - Shipping**
  - Need for global effort and cooperation of public and private sectors
  - Fuel price and availability will be decisive
  - Cost reductions in technology and RE will make alternative fuels competitive in the medium to long term
  - Life cycle emissions will have to be considered

Thank you

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Hydrogen production costs - Currently accelerating investments in electrolysers worldwide

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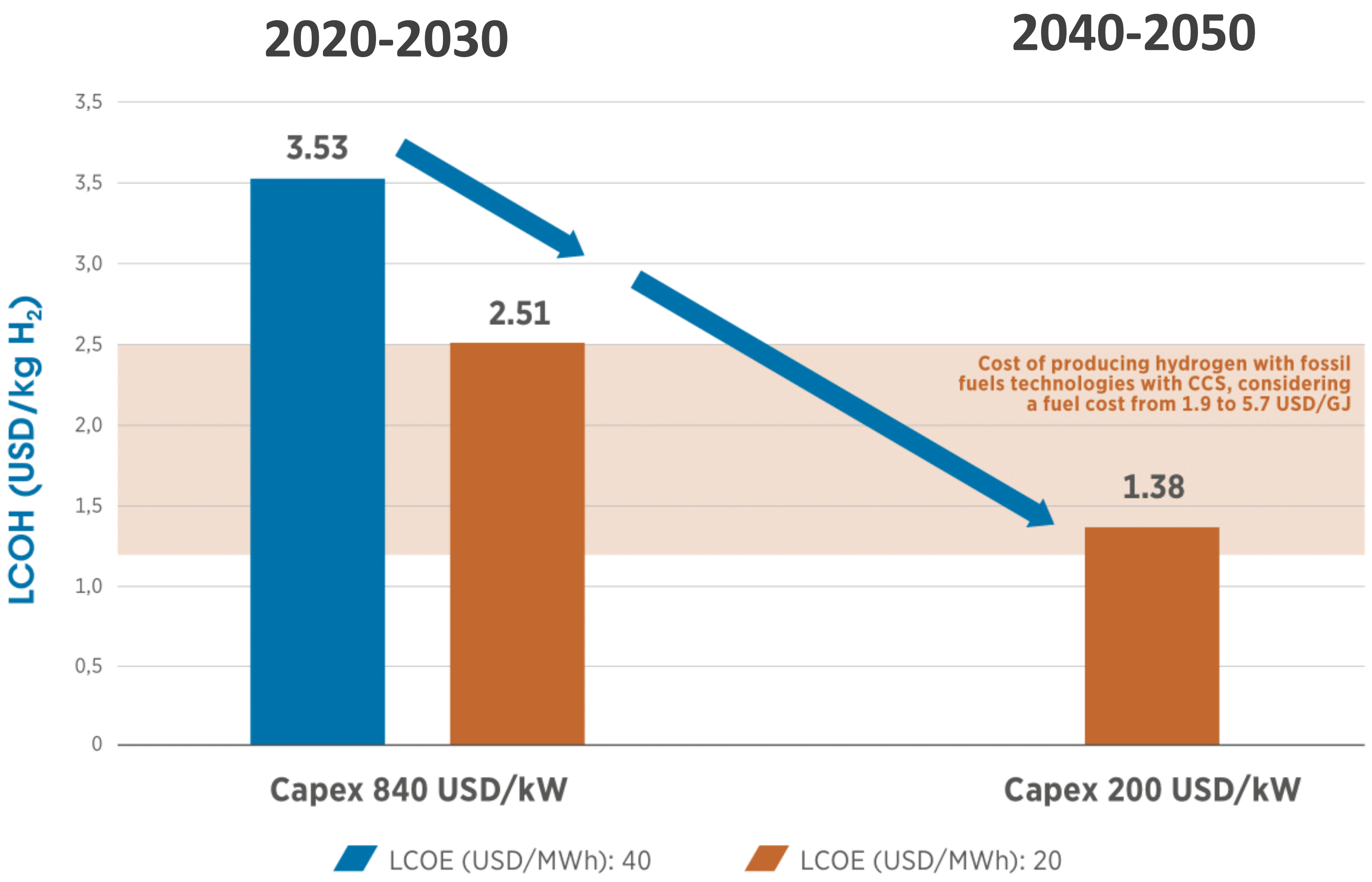
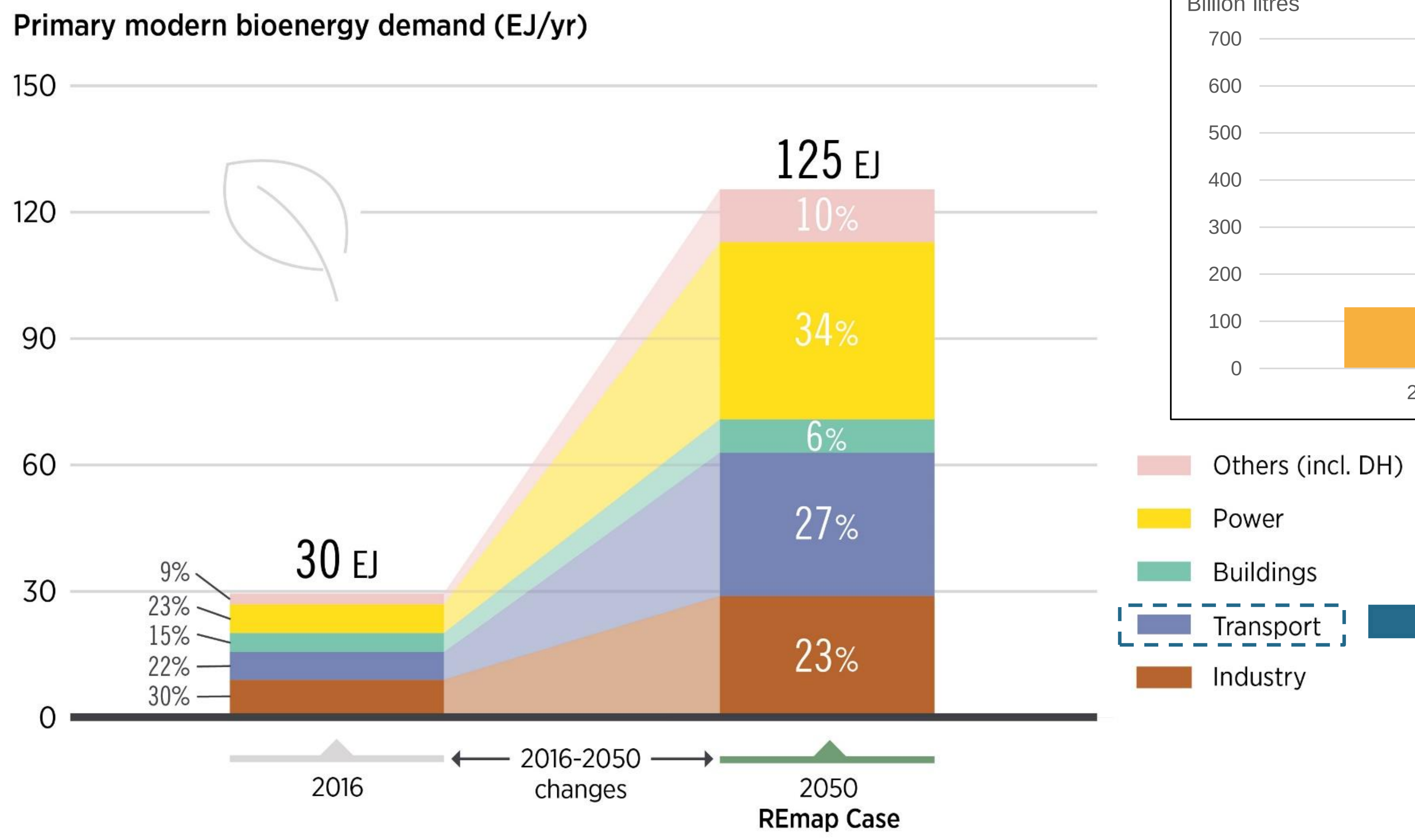


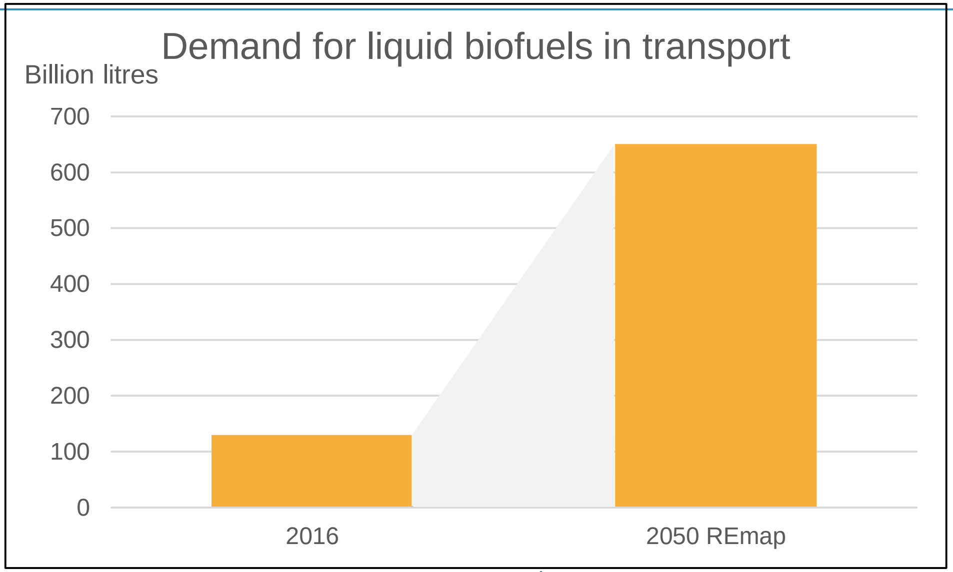
- Energy content 8 kg hydrogen = 1 GJ natural gas. Natural gas wholesale price today USD 2/GJ (US) – USD 8/GJ
- Replacing gas with hydrogen - saving 0.056 t CO2/GJ – translates into 100-200 USD/t CO2
- This would apply to ammonia, synthetic methanol from H2/CO2

Hydrogen from renewables is close to competitiveness at best solar and wind sites

Key assumptions - Electrolyser load factor: 4200 hours (48%), conversion efficiency 75%

Modern bioenergy deployment should be over four times larger than the current level





Data based on the Global Energy Transformation: A Roadmap to 2050 (IRENA 2019)