

Hydrogen as Marine Fuel Infrastructure and Fuel Supply Challenges

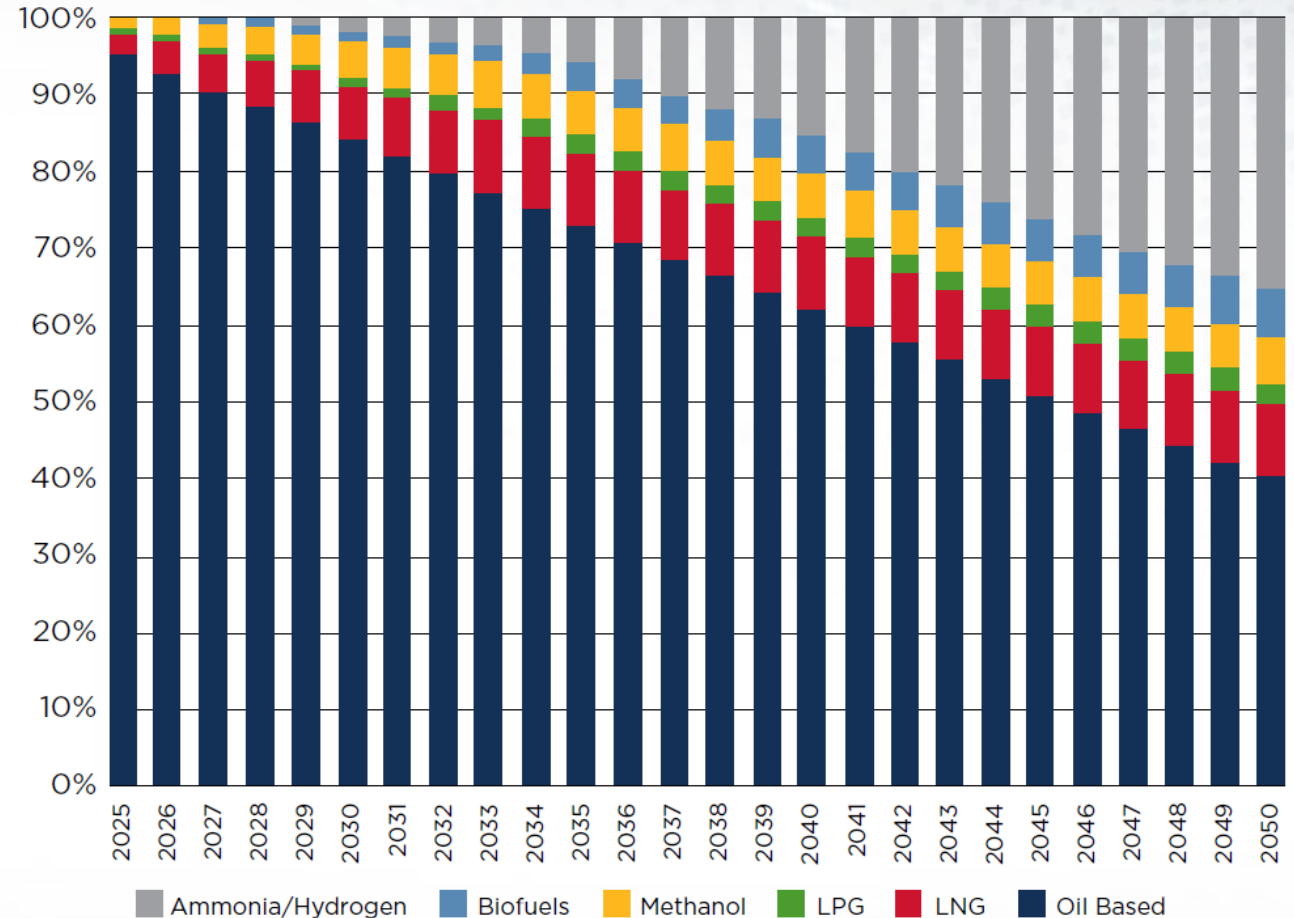


2021 IMO Symposium on Low- and Zero-Carbon Fuels
February 9-10, 2021

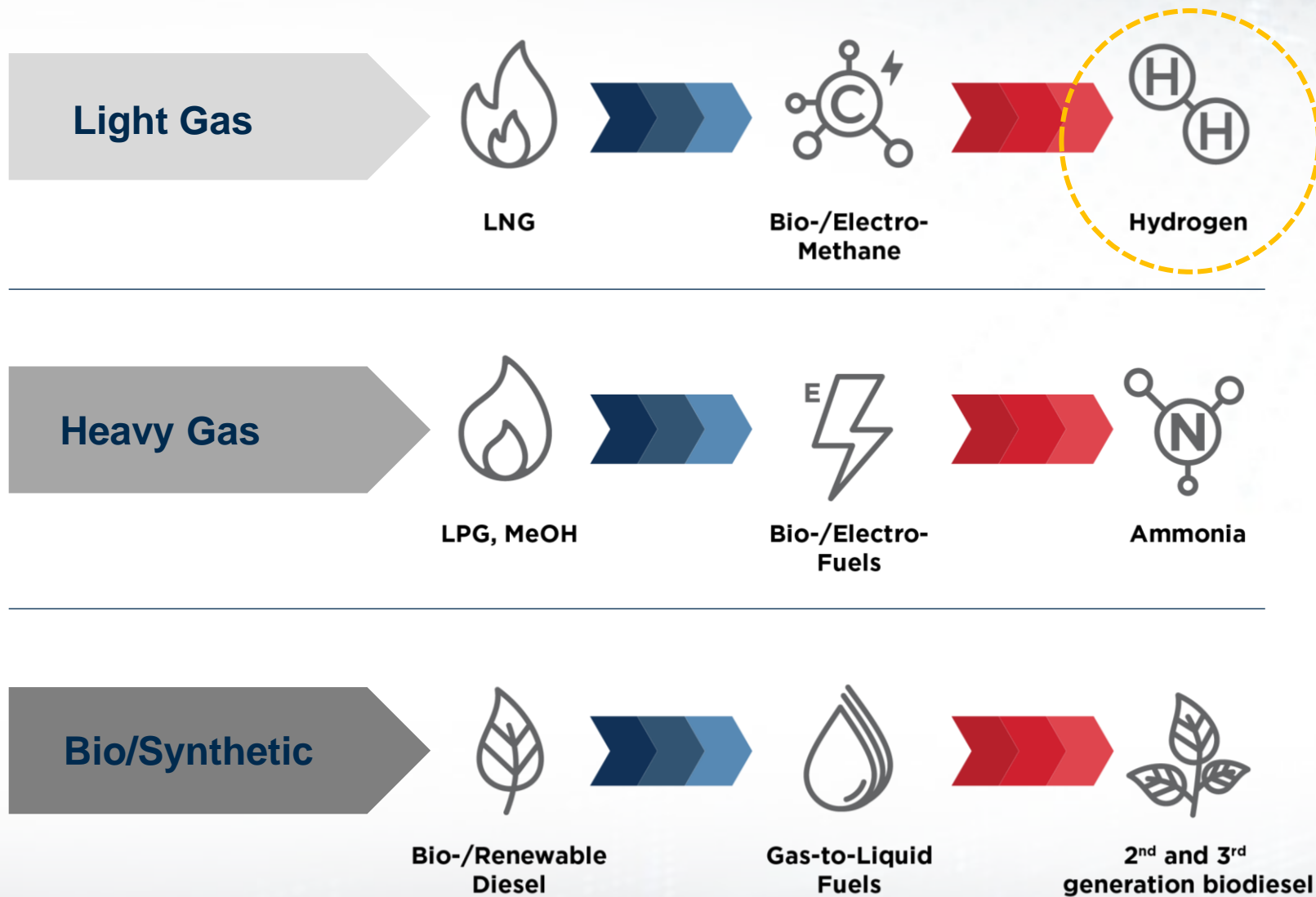


Decarbonization Forecast and Fuel Mix

- ABS 2020 Low Carbon Shipping Outlook
- Fuel mix projected to 2050
 - 40% oil-based fuels in 2050
 - 35% ammonia/hydrogen use
- Decarbonization scenarios:
 - The use of low- and zero-carbon fuels will have a significant effect, but it may not be enough to meet the IMO targets
 - Additional measures needed for Accelerated Climate Action

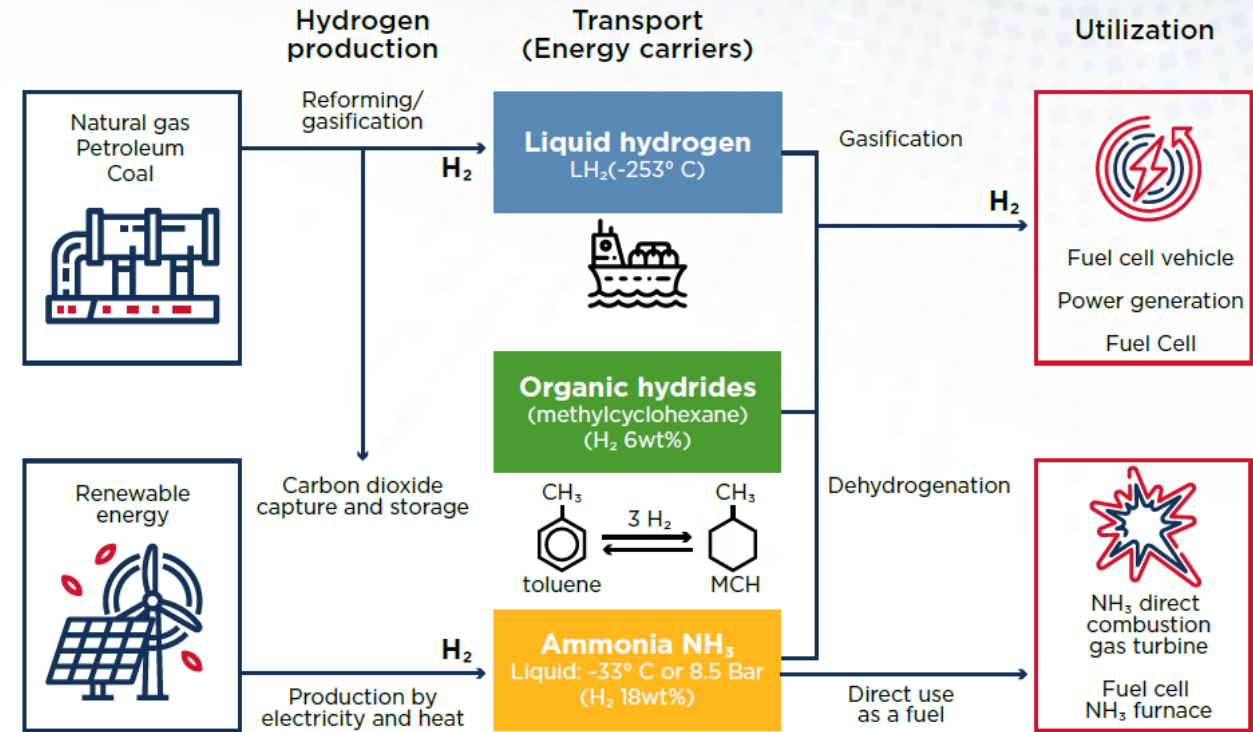


The Three Fuel Pathways of the Future



Production of Hydrogen

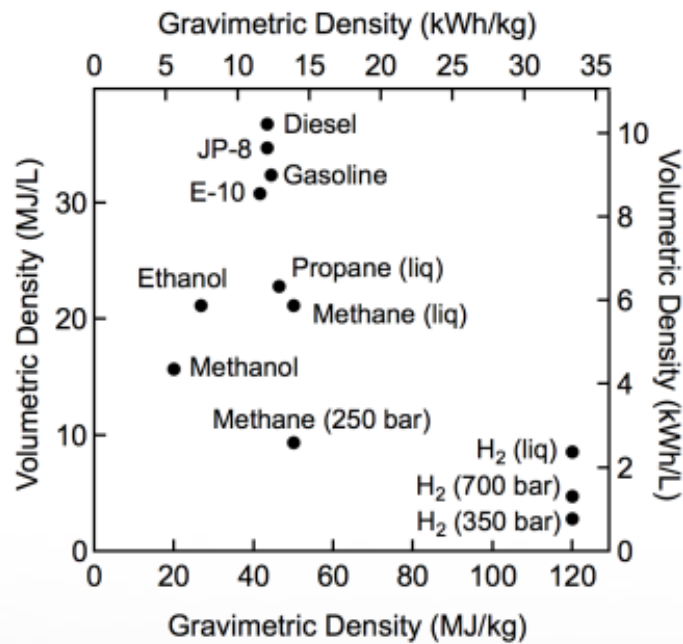
- 2019 global production (IEA)
 - 75% from natural gas
 - 23% from coal
- Ammonia can be produced along the way
- US currently produces ~10M ton of H₂ annually
- Can be transported using Liquid Organic Hydrogen Carriers (LOHC)
- If combined with carbon capture and sequestration, hydrocarbon fuels can be produced (e.g. CH₄)
- Hydrogen is significant as marine fuel but also as cargo
 - Hydrogen Council 2050 goals: 18% of worldwide energy demand, 6 Gton of CO₂ reductions annually, \$2.5 trillion in annual sales, and 30 million jobs created
 - Global hydrogen industry estimated at \$7.5 bn by 2050



Source: JIST

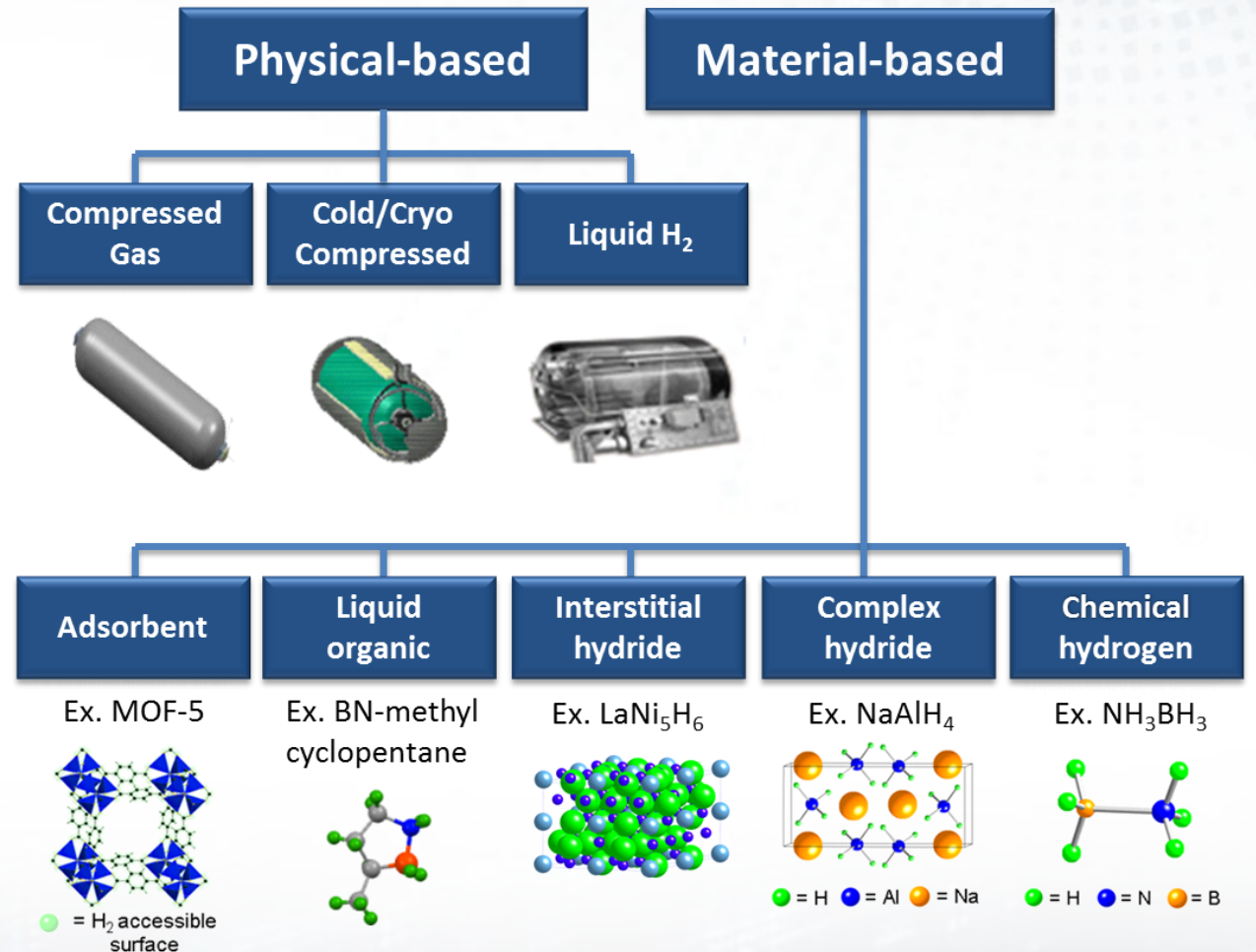
Storage

- Hydrogen can be stored as a gas or liquid
 - Compressed gas at 350-700 bar
 - Liquid cryogenic storage at -253°C , 1 bar
 - On or within solids



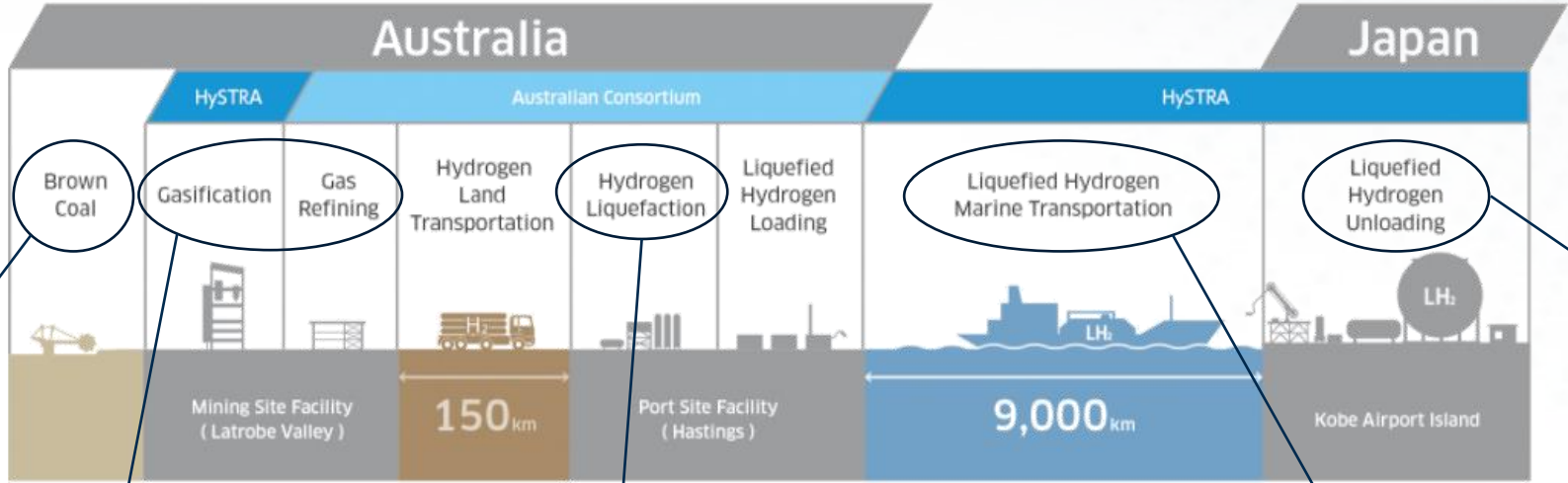
Source: US DOE

How is hydrogen stored?



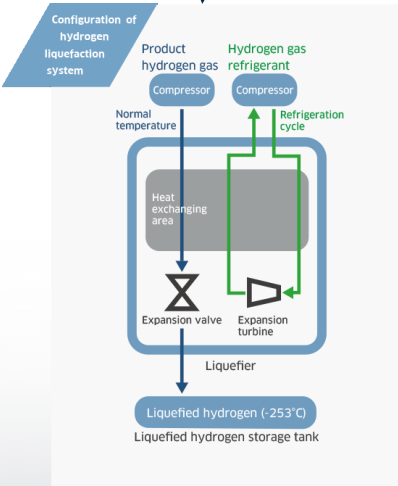
Source: US DOE

Supply Chain Framework and Challenges



Large reserves of coal and natural gas, but carbon-intensive production – Need regulations that will promote the use of green hydrogen (e.g. lifecycle emissions accounting)

Currently limited production facilities but increasing - Focus on green hydrogen production Australia: 23 hydrogen production demonstration projects



Hydrogen Liquefaction System required at bunkering facilities

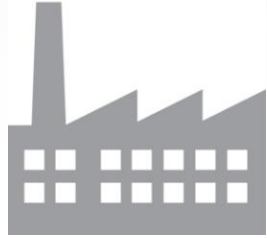
One Liquefied Hydrogen Carrier in existence by KHI
Need for LHC standards and rules
Need rules for alternative power generation systems e.g. fuel cells

Requirement for Hydrogen Liquefaction Systems and advanced storage tanks

Source: KHI



Challenges and Opportunities



Production

- Fossil fuel conversion
- Biomass and waste conversion
- Electrolysis
- Thermal water splitting
- Biological
- Photochemical
- Direct hydrogen carrier production



Distribution

- Hydrogen distribution more challenging than other fuels due to stringent storage requirements (temperature, diffusivity)
- Points to localized hydrogen production stations



Bunkering

- Port site facilities currently limited
- Experience gained from LNG bunkering methods, but more stringent requirements posed by hydrogen

Thank you
