

National Hydrogen Roadmap

'Pathways to an economically sustainable hydrogen industry'

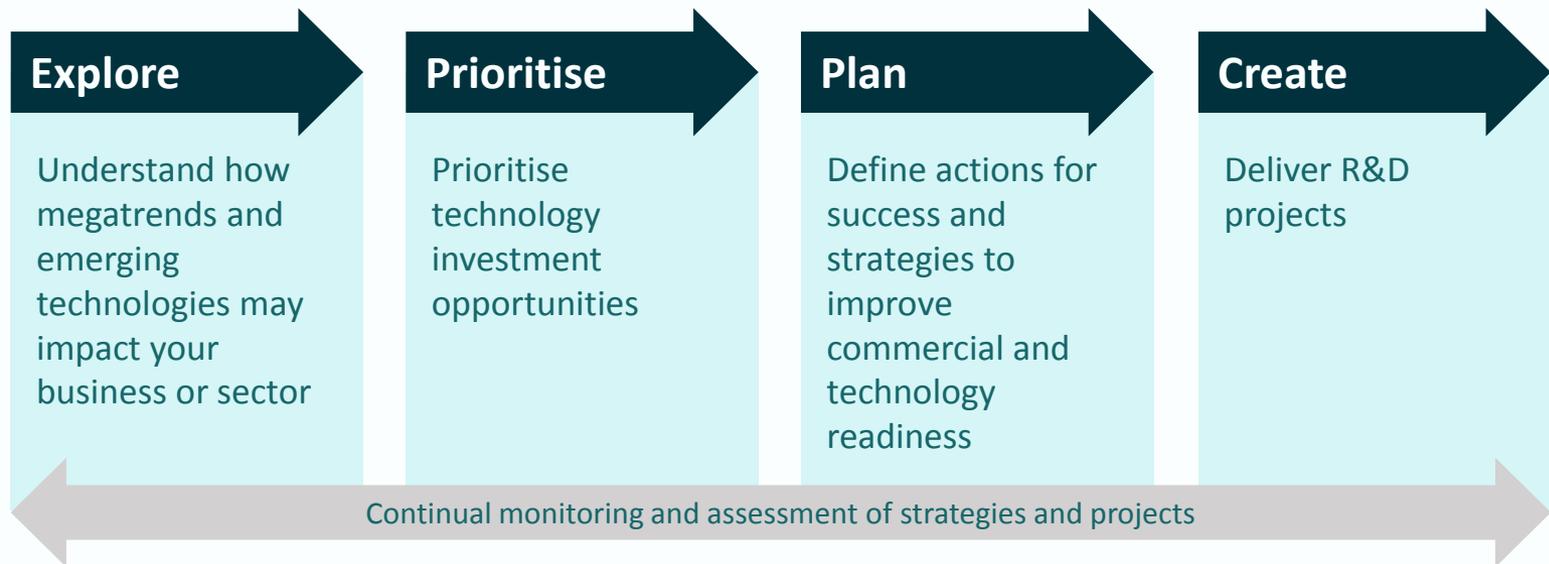
Workshop: R&D needs for export
November 2018

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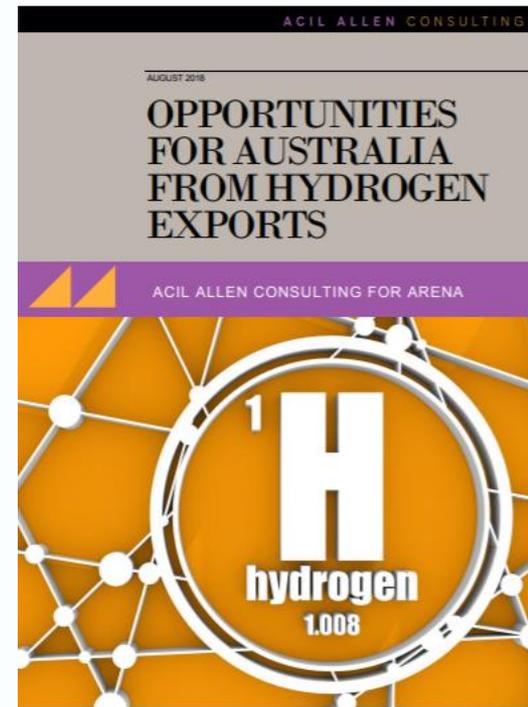
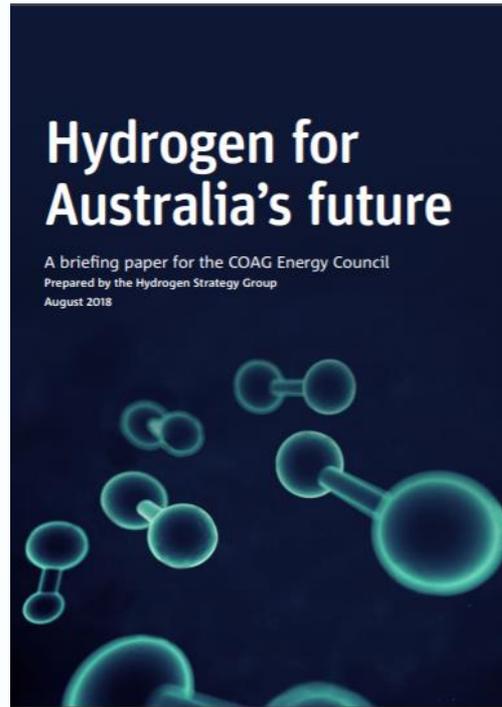
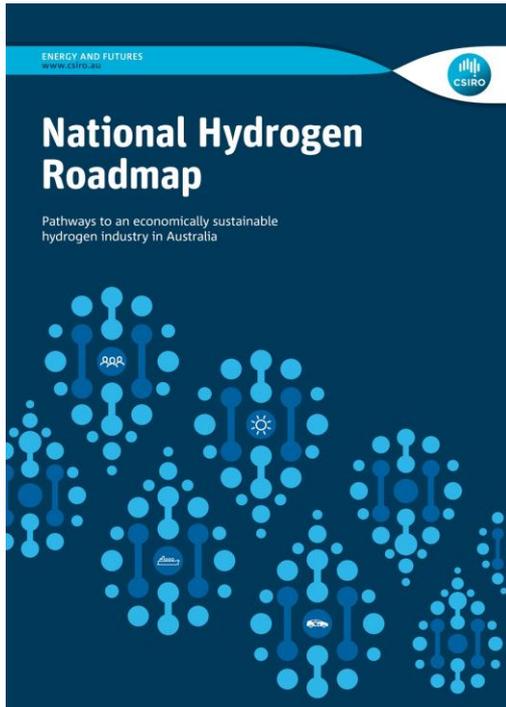


Background - CSIRO Futures

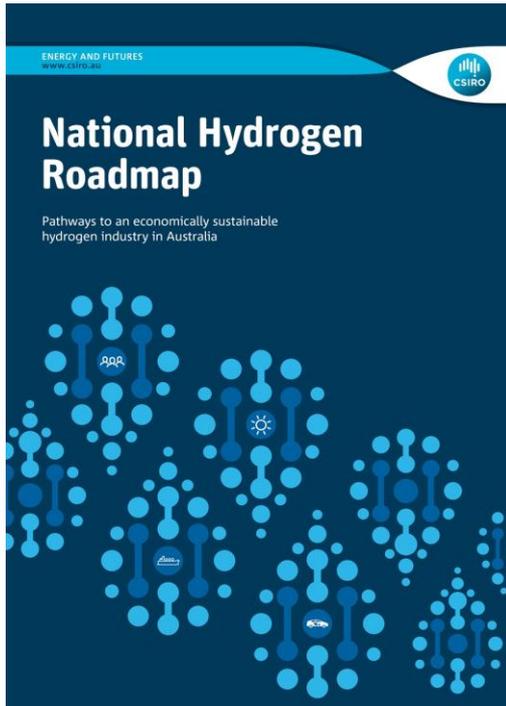
CSIRO Futures is the strategic advisory arm of Australia's national science agency. We leverage the deep expertise of CSIRO's research professionals to help Australia's largest companies and government 'translate science into strategy'.



Recent hydrogen activity



National Hydrogen Roadmap objective

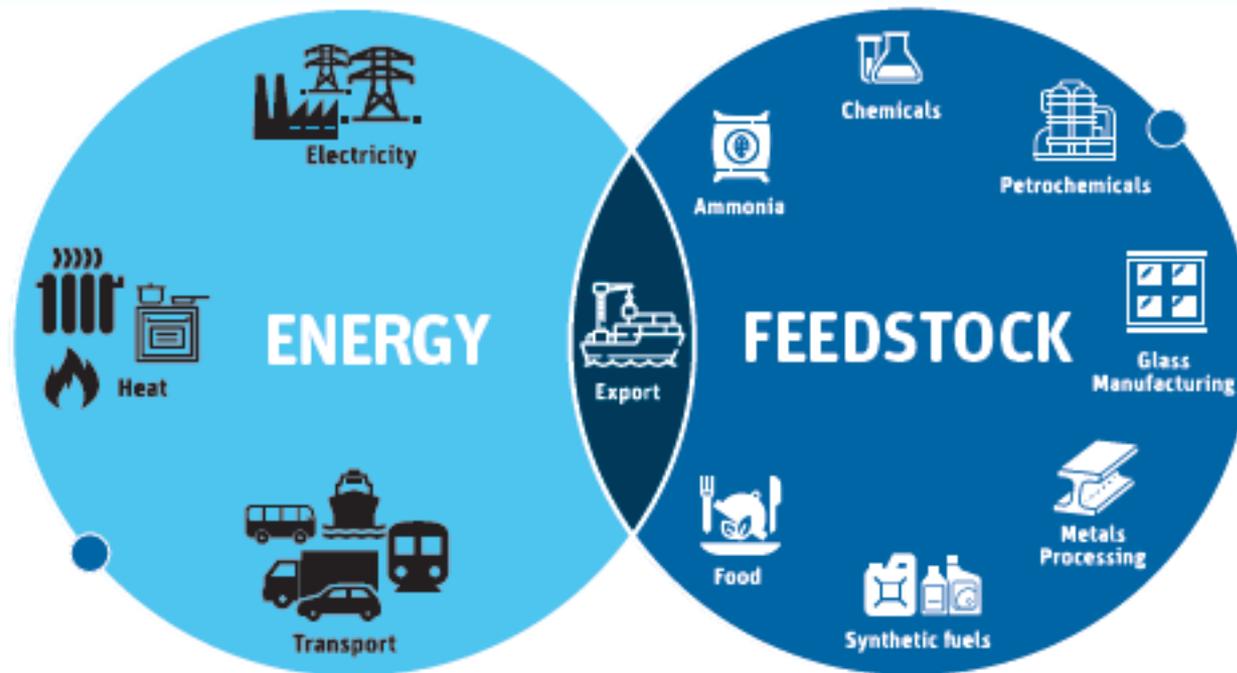


Primary objective: To provide a blueprint for the development of a an economically sustainable domestic and export hydrogen industry in Australia

- Designed to help coordinate and inform investment amongst industry, government and research

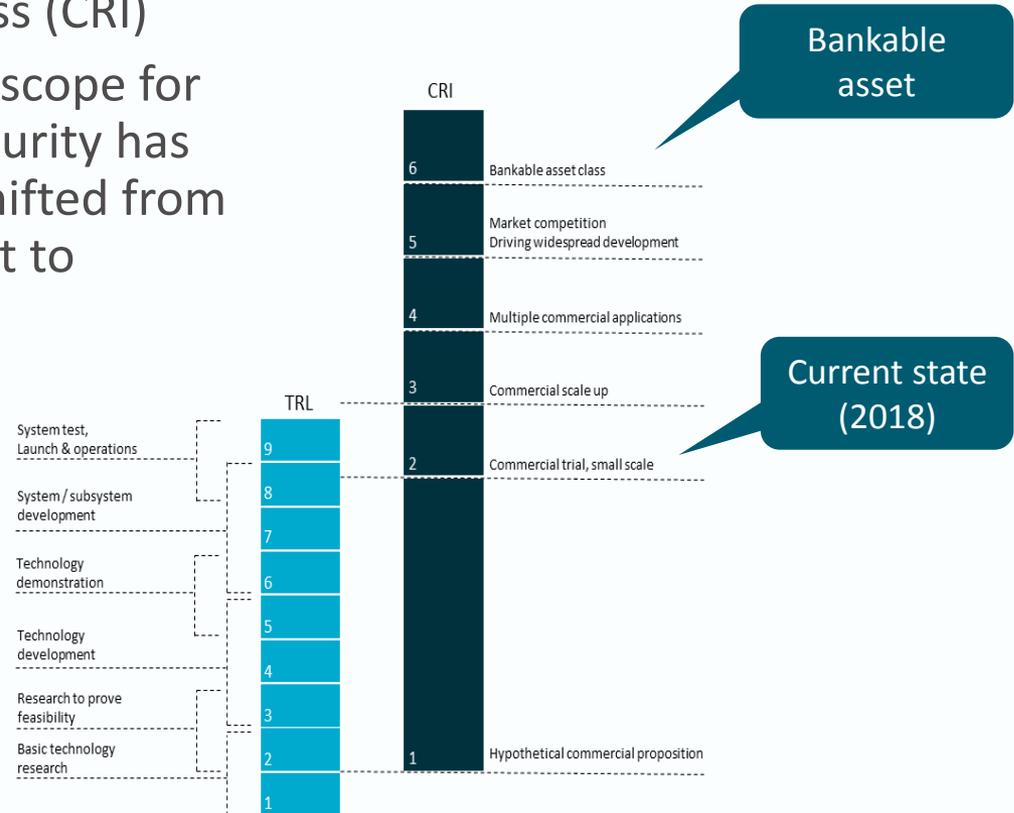
Why hydrogen?

- 'Clean' hydrogen, produced from low or zero emissions sources, is a versatile energy carrier and feedstock that can enable deep decarbonisation across the energy and industrial sectors
- It is the ability to simultaneously service multiple points of demand that makes hydrogen so attractive

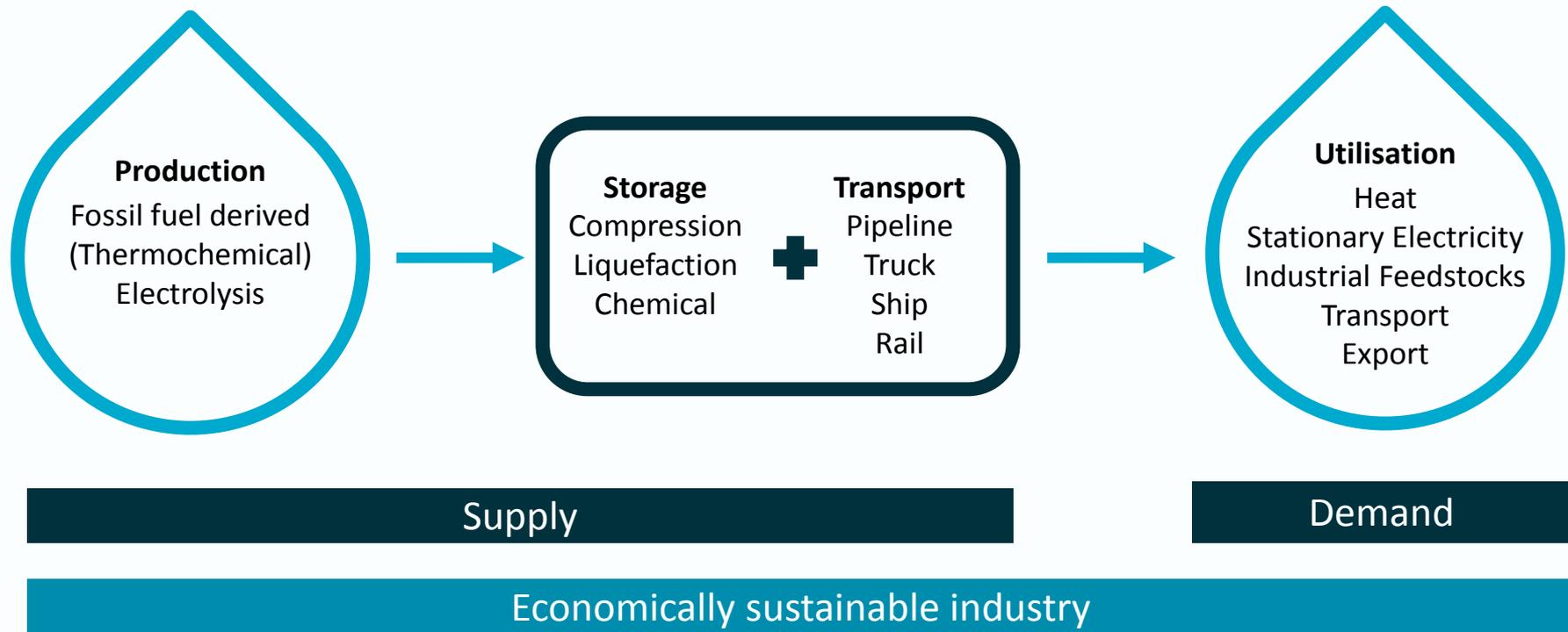


Why now?

- Hydrogen value chain now underpinned by a series of mature technologies
 - i.e. high technological readiness (TRL) but low commercial readiness (CRI)
- Although there is considerable scope for further R&D, technological maturity has meant that the narrative has shifted from one of technology development to **market activation**



Hydrogen value chain



Understanding the Roadmap

Methodology

1. Base case (2018) modelling of mature technologies

2. Identification of material cost drivers, e.g.

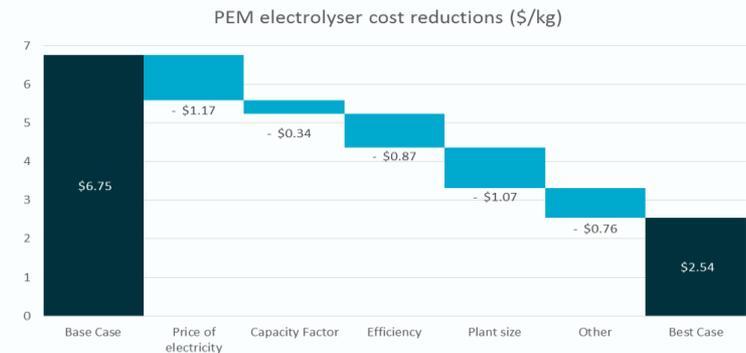
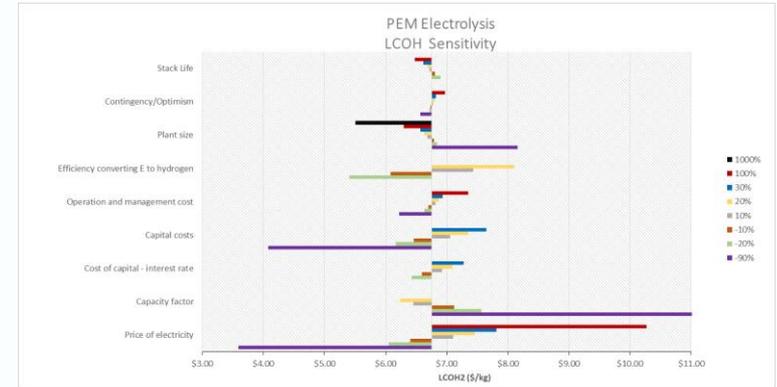
- Energy input cost
- Plant size
- Capacity factor
- Efficiency

3. Identification of key investment priorities

- Commercial – implications, opportunities, business models, role of govt
- Policy/regulatory – address market failure, economic/technical standards
- RD&D – Incremental improvements and next wave of disruption
- Social licence – ‘Normalising risk’

4. Modelling of best case achieved by ~2025:

- Cumulative impact of investment priorities



Roadmap Synthesis

Key message

- In light of current maturity, strategic investments from the public and private sector could see hydrogen become an **economically sustainable industry**
- Barriers to market activation stem from both a lack of infrastructure supporting markets and/or the cost of hydrogen supply
- Development of an appropriate policy framework could create a 'market pull' for hydrogen. It is expected that investment in value chain infrastructure will follow

Understanding the roadmap

H₂ Commercially competitive cost curve

\$/kg



Potential market applications

Target cost of hydrogen

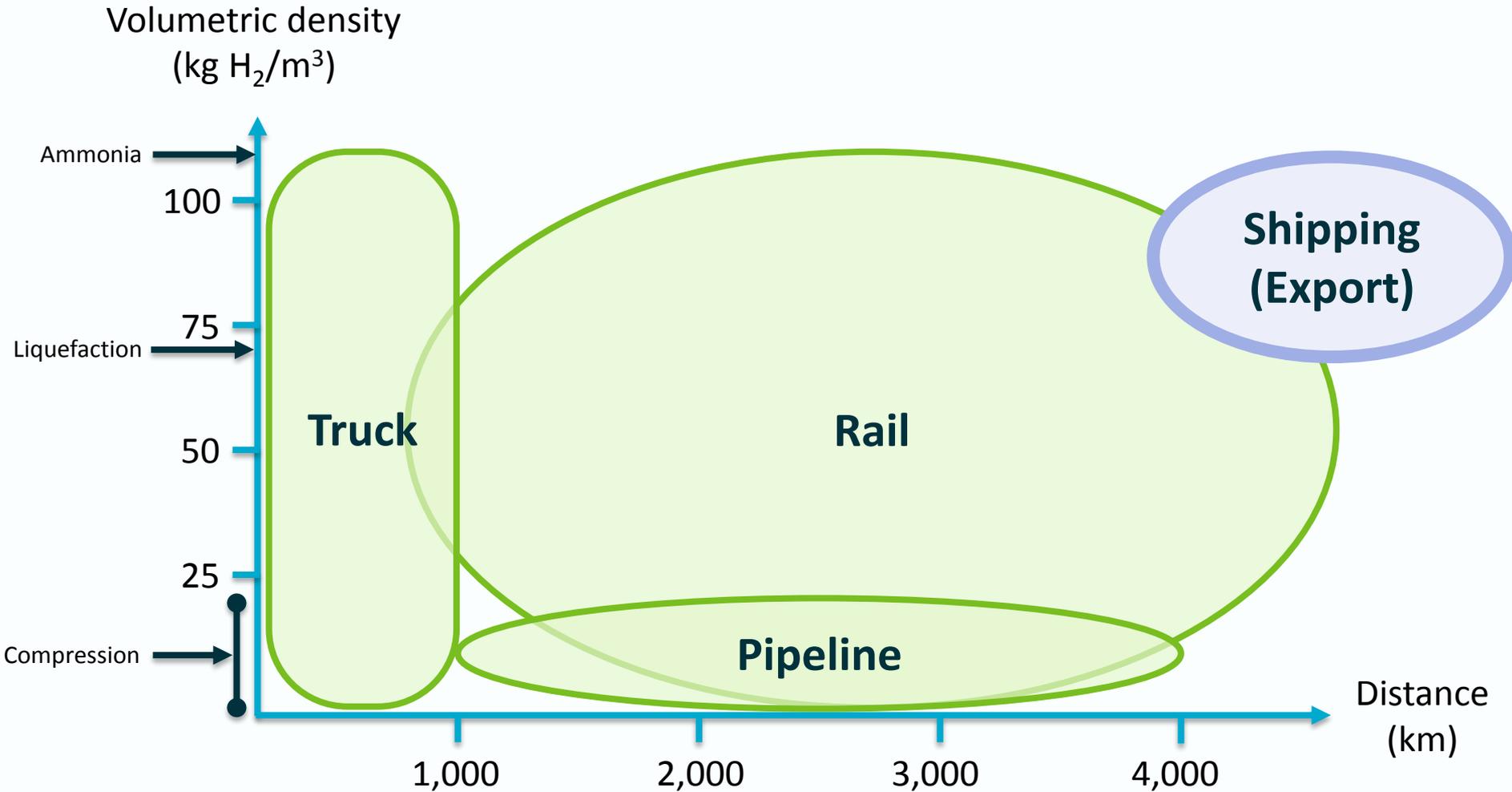
- Price point at which hydrogen could become competitive on a commercial basis with other technologies and feedstocks (e.g. natural gas)
- It does not include the following factors, which could all improve its competitiveness:
 - Localisation of relevant supply chains
 - Industrialisation & manufacture automation
 - Establishment of an export industry
 - Environmental cost/carbon pricing risk
 - Energy supply risk



- This cost curve is not the only driver – Target markets also influenced by stakeholder interest (i.e. H₂ is one of the few ways to decarbonise certain sectors), policy and existing infrastructure

R&D needs for export

Optimal hydrogen storage & transportation options



R&D needs for export

Japan hedging bets across 3 carrier methods...

Liquefaction

Advantages:

- Transporting high purity hydrogen
- No energy requirement for importer

Disadvantages:

- New infrastructure
- H2 Boil-off
- High cost

Ammonia

Advantages:

- Existing infrastructure (e.g. oil tankers, ammonia ships)
- Shipping at room temperature

Disadvantages:

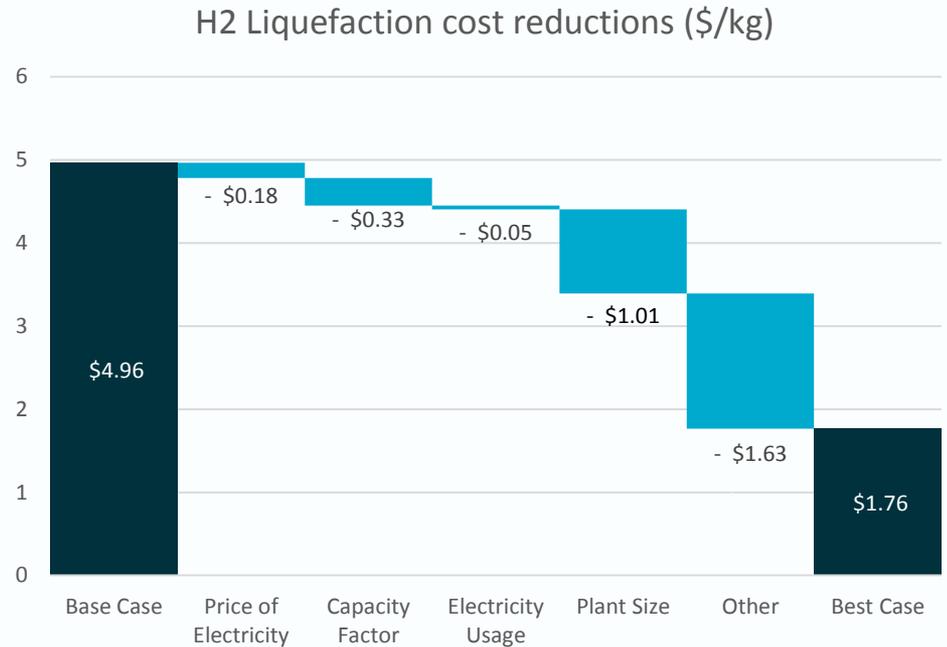
- Toxicity
- Regulations
- Energy and cost penalty for recovery of high purity H2 (if required)

Toluene/MCH

Storage & Transport

Liquefaction

- Improvements in liquefaction:
 - Electricity pricing
 - Plant capacity
 - **R&D measures designed to improve plant efficiency and maintain temperature**

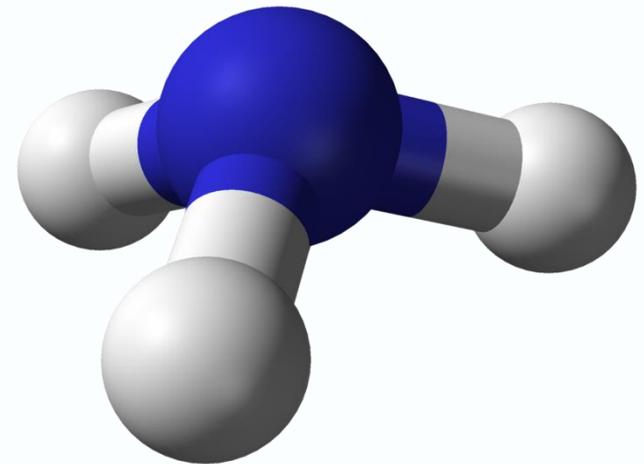


- First-of-kind liquefied hydrogen ship: KHI in collaboration with Shell
 - Capable of shipping 1250m³ (88,500kg) liquid hydrogen (LH₂) from Australia (Victoria) to Japan in 16 days

Storage & Transport

Ammonia

- Key R&D themes:
 - Stepping away from Haber-Bosch to more decentralised forms of ammonia synthesis
 - Direct ammonia use
 - Recovery of high-purity hydrogen for use in FCs (e.g. CSIRO membrane)



Thank you

