National Hydrogen Roadmap
‘Pathways to an economically sustainable hydrogen industry’

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Why now?

Globally, the hydrogen industry is underpinned by a series of mature technologies, and relevant markets are on the verge of reaching a ‘tipping point’.

- This has meant that the hydrogen narrative has shifted from one of technology development to market activation.
Australia’s Hydrogen Production Potential

**Electrochemical**

- Electrolysis provides a more distributed, modular option that can scale according to demand
- Both PEM and Alkaline Electrolysis are expected to be utilised to meet Australia’s hydrogen export demand prior to 2030
- Electrolysis may be paired with dedicated renewable energy or grid connected electricity

![Wind](image1)

![Solar](image2)

Wind

Solar
Russia’s Hydrogen Production Potential

Thermochemical

- Most of the world’s ‘dirty’ hydrogen is currently produced using steam methane reforming of natural gas & coal gasification
- Australia has world class CCS potential & experience

Fossil Fuel Resources

CCS Resources
National Hydrogen Roadmap objective

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

**Secondary Objectives:**

- Bring together the broad H₂ stakeholder group (industry, government, research) to develop a clear view of the opportunity for Australia
- Inform investment decisions (industry, government and research)
Hydrogen applications

Key applications relevant to Australia

**Commodities export:**
- Hydrogen
- Ammonia
- Synthetic fuels (e.g. Methanol)
- Natural Gas (synthetic)

**Transport:**
- Passenger vehicles
- Heavy vehicles (bus, trucks)
- Shipping
- Rail (diesel and electric)

**Heat:**
- Residential
- Commercial heat at different temperature ranges

**Industrial:**
- Petrochemical
- Metals (steel, copper, nickel)
- Chemicals
- Food
- Synthetic fuels

**Power/Electricity:**
- Energy storage
- Grid support
  - Stability
  - Reliability
- Remote area power systems
Hydrogen value chain

Production
- Thermochemical (Fossil fuel derived)
- Electrolysis

Storage
- Compression
- Liquefaction
- Chemical

Transport
- Pipeline
- Truck
- Ship
- Rail

Utilisation
- Heat
- Stationary Electricity
- Industrial Feedstocks
- Transport

Supply

Demand

Economically sustainable industry
Understanding the Roadmap

Methodology


2. Identification of material cost drivers

1. Identification of key investment priorities
   - Commercial
   - Policy/regulatory
   - RD&D
   - Social licence

2. Modelling of best case achieved by 2030:
   - Cumulative impact of investment priorities
Hydrogen production by electrolysis

Identification of key cost drivers

Tornado Charts: Sensitivities modelled using realistic changes with time, then used to derive ‘best case’ plot

- Plant size
- Efficiency
- Capital cost
- Electricity cost

Renewable Electricity
8c to 4c per kwh

10x increase in plant size
(1MW to 10MW)

Capacity factor
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 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
Applications in this zone are viable based on $\text{H}_2$ cost in 2018 (Base Case) (but may have other barriers).

Applications in this zone have cost barriers in 2018, but are projected to become cost competitive ~2025.

Applications in this zone have cost (and perhaps other) barriers to overcome.
Applications & The H₂ Cost Curve

Legend
- Expected H₂ supply cost (including compression)
- Infrastructure barrier
- Base case (2018) H₂ supply cost barrier
- Best case (~2025) H₂ supply cost barrier
- Infrastructure and H₂ supply cost barrier

$/kg

- Passenger vehicles
- Buses
- Trucks
- Remote Area Power Systems
- Export
- Industrial feedstocks
- Grid firming services
- Residential heat
- Synthetic fuels

2020 2025 2030
Remote Area Power Systems (RAPS)

Legend
- Expected H₂ supply cost (including compression)
- Infrastructure barrier
- Base case (2018) H₂ supply cost barrier
- Best case (~2025) H₂ supply cost barrier
- Infrastructure and H₂ supply cost barrier

2020 2025 2030

$/kg

Passenger vehicles
Buses
Trucks
Remote Area Power Systems
Export
Industrial feedstocks
Grid firming services
Residential heat
Synthetic fuels

Expected H₂ supply cost (including compression)
Hydrogen in Remote Area Power Systems (RAPS)

Key Findings

- Potential to displace diesel at a cost of $440/MWh

- Hydrogen based RAPS system
  - Scaleable & long term storage
  - Operation in harsh conditions

- Flexible Models
  - Centralised: large scale H2 generation with H2 or electricity distribution
  - Decentralised: localised generation & consumption (prosumer models later)

- Investment Priorities
  - Technical: Hydrogen turbines for electricity generation (H2, Ammonia, H2/NG)
  - Fuel Cells: Reversible & combined electrolyser – fuel cell systems
RAPS Options
In the light of recent technological and commercial developments, market activation is the key priority for developing an economically sustainable hydrogen industry in Australia.

Barriers to market activation stem from both a lack of infrastructure supporting markets and/or the cost of hydrogen supply.

The opportunity for clean hydrogen to compete favourably on cost in many local applications is within reach and achievable by 2025.

The development of an export industry represents a potential ‘game changer’ for hydrogen and the broader energy sector due to associated increases in scale.

Development of an appropriate policy framework could create a local ‘market pull’ for hydrogen. It is expected that investment in value chain infrastructure will follow.
A Collaboration between CSIRO Energy & CSIRO Futures

CSIRO Futures

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CSIRO Energy

Delivering the R&D solutions that will enhance Australia’s economic competitiveness and regional energy security while enabling the transition to a lower emissions energy future.
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