Enabling the decarbonisation of Australia's energy networks

RP1.2-02: Techno-economic modelling of fuel production processes

This project sought to develop techno-economic and process models of low CO_2 emission hydrogen production processes that could be used to identify the parameters that drive their technical and economic viability and compare alternate fuel systems/approaches. Models were developed for a variety of feedstocks to allow for quantitative cost comparisons (for an overview see *Table 1* below).

The original work was done during 2019-21 in partnership with the University of Queensland, the University of Adelaide, and the University of Melbourne, with advice from several industry partners. This work was then supplemented and revised in 2022 to refine the analysis of the electrolysis pathways and hydrogen carriers, and an associated Summary Report was released in November 2023.

A total of 22 production pathways and nine hydrogen carrier scenarios were investigated. Four feedstocks were considered: water, biomass, natural gas, and coal. For those cases involving a fossil feedstock there was a non-negotiable requirement for carbon capture and storage (CCS) to reduce emissions and the additional energy penalties, capital and operating costs were all accounted for. Additionally, for biomass pathways, the cost of adding CCS to yield negative emissions was investigated.

Table 1: Overview of production options and processes investigated in the project

Technology/production area	Specific technologies and pathways investigated
Natural Gas to Hydrogen Pathways (Blue Hydrogen)	• Conventional technologies (w CCS): ○ Standalone steam methane reforming ○ Combined steam methane reforming with post autothermal reforming of methane ○ Auto-thermal reforming • Emerging technologies: ○ Methane pyrolysis using a solid catalyst ○ Methane pyrolysis using a molten liquid catalyst
Coal to Hydrogen Pathways (Blue Hydrogen)	• Two gasifier technologies (w CCS) – entrained flow and dual fluidised bed – were investigated for hydrogen production across four cases
Biomass to Hydrogen (Green Hydrogen) and Biomethane Pathways	• Two technologies for thermochemical conversion of biomass to hydrogen were investigated: pyrolysis and gasification • The conversion of biomass to biomethane was also explored
Electricity to Hydrogen Pathways (Green Hydrogen)	• Alkaline Water electrolysis (AWE) • Proton exchange membrane (PEM)
Hydrogen Carriers	• Liquid hydrogen (cryogenic compression process) • Green Methanol (three different processes: methanol from syngas; and methanol from gaseous CO_2 or methanol from liquid CO_2 – both involving CO_2 hydrogenation) • Green Ammonia (Haber-Bosch process)

The project reports, including the updated 2023 Summary Report, present estimates for the levelized cost of hydrogen (LCOH) for each feedstock based on consistent input assumptions at the time of the completion of the original study in 2021 (also see *Table 2*). The levelized cost of the hydrogen carriers is also estimated (as the marginal cost of production, i.e. excluding the cost of the hydrogen feedstock).

The design basis and core costing assumptions are set out in the Summary Report, including:

- Plant size;
- Quality of hydrogen produced;

- Utility and feedstock costs; and
- Discounted cash flow parameters.

Table 2: Most competitive LCOH for each feedstock

Feedstock	Pathway	LCOH (\$/kg-H_2)[1]
Natural gas (NG) / Coal seam gas (CSG)	Autothermal reforming with CO_2 capture optimised for process efficiency	2.92
Coal	Gasification of Victorian Brown Coal in an entrained flow gasifier.	4.12
Biomass	Gasification of biomass in a dual fluidised bed gasifier.	4.66
Water	Alkaline electrolysis	6.38

Modelling of the alternative hydrogen carriers found ammonia to be the most cost-effective carrier on a mass basis, adding only \$1.55/kg-H_2. Liquified hydrogen and methanol[2] added \$2.27/kg-H_2 and \$2.06/kg-H_2 to the LCOH respectively.

For more information see the Summary Report (2023) and Final Milestone Report (2021).

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[1] As at study completion in 2021
[2] CO_2 used for methanol production was either biogenic in origin or from direct air capture. Fossil CO_2 was not used.