# Coupling Process and Life Cycle Engineering: A case study for Proton Exchange Membrane Electrolysis in New South Wales

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## Australian low-emission hydrogen background

### Context

Reducing impact on climate change is critical and low-emission technologies to reach net-zero greenhouse gas emissions should be fostered [1].

Hydrogen has a strong has a strong decarbonisation potential for heavy industry if produced via renewable energy [1]. Large renewable energy zones (REZ) are planned in NSW where hydrogen could be produced in substantial quantities [2].

Proton exchange membrane (PEM) electrolysis is coined to be a leading technology in low emission hydrogen production [3].

### Problem

There is currently no comprehensive understanding of the climate change impact of electrolytic hydrogen production in New South Wales.

Current life cycle inventory models for proton exchange membrane electrolysis rely on pilot scale data and use static values for efficiency. This leads to inaccurate techno-environmental assessment of PEM electrolysis.

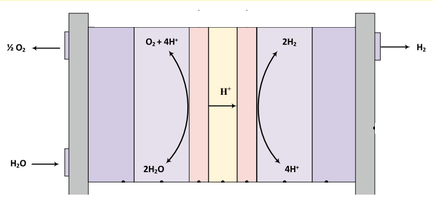
### Solution & benefits

Electrolysis plant modelling for parametric life cycle inventory analysis → Better life cycle inventories!

&

Geospatial impact assessment in NSW → To see where it should be implemented

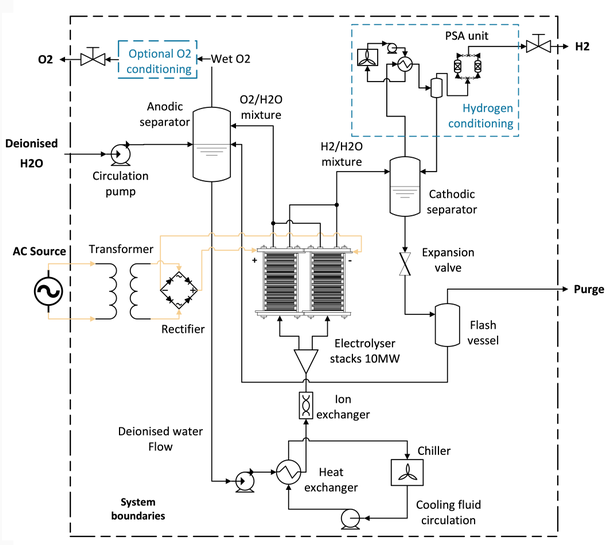
## Electrochemical Process Engineering




### 1D - electrolysis cell modelling

$$U_{cell} = U_{rev} + \eta_{ohm} + \eta_{act} + \eta_{con} + \eta_{degrad}$$

The proton exchange membrane electrolysis cell was modelled on Julia to capture the actual plant performance given the technical parameters. This enables life cycle engineering options using a bottom-up approach [3].




Block flow diagram PEM electrolysis plant model [3].

### Key parameters

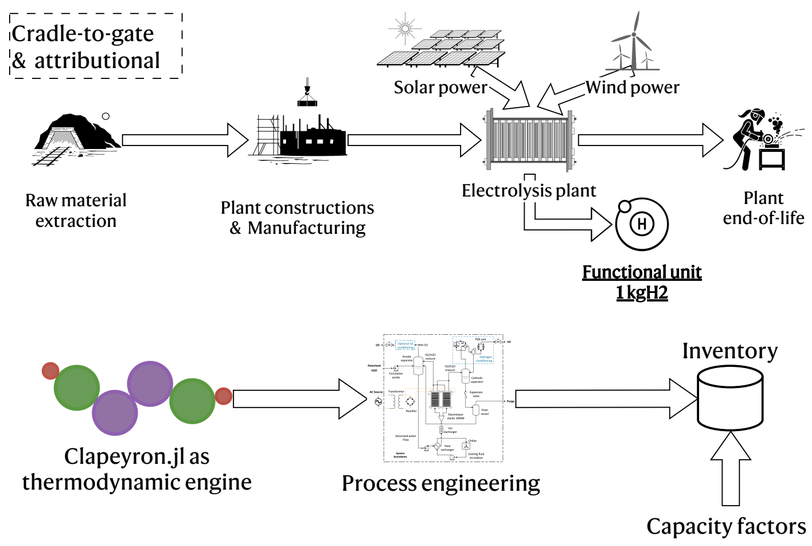
- Specific energy consumption (SEC)
- Membrane thickness
- Instrinsic catalytic activity

### Plant modelling

The plant was modelled using Clapeyron.jl as thermodynamic engine. Plant control strategy was based on the inlet water temperature. Process units were modelled using high-level models, and the results were tested against Aspen plus®. Thermochemical properties of binary mixtures were obtained from the Aspen plus® analyser.

## Parametric Life Cycle Assessment

Evaluating the environmental impact on climate change of 1kg of electrolytic hydrogen produced from wind and solar energy in NSW.

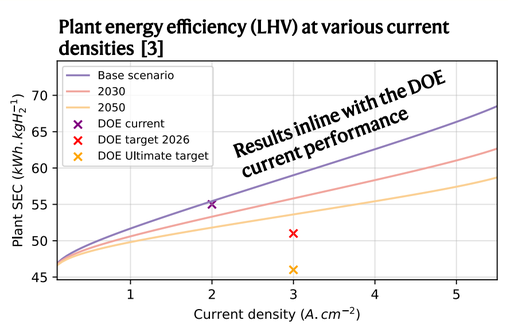


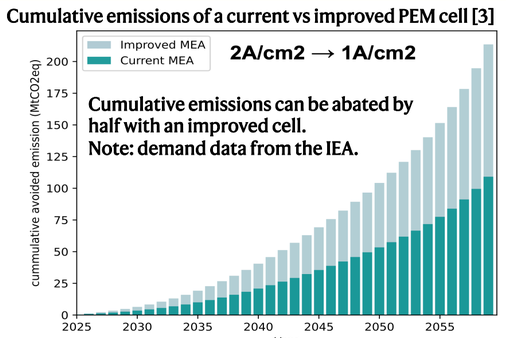

### Goal & scope definition

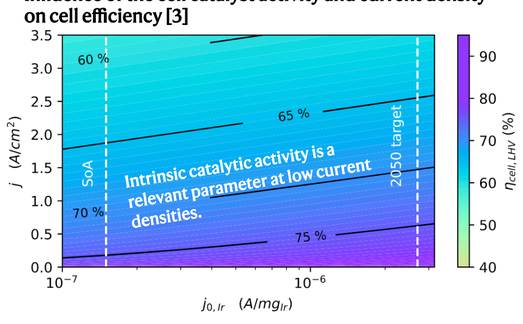
### Life cycle inventory

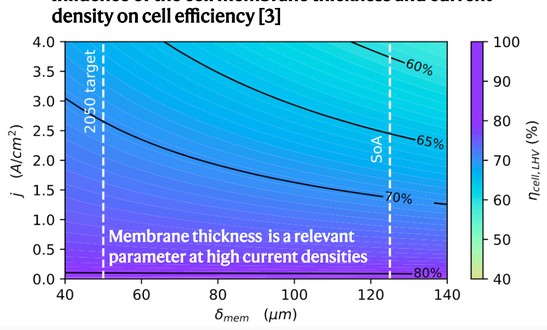
### Impact assessment & Interpretation

## Electrolysis plant technical performance



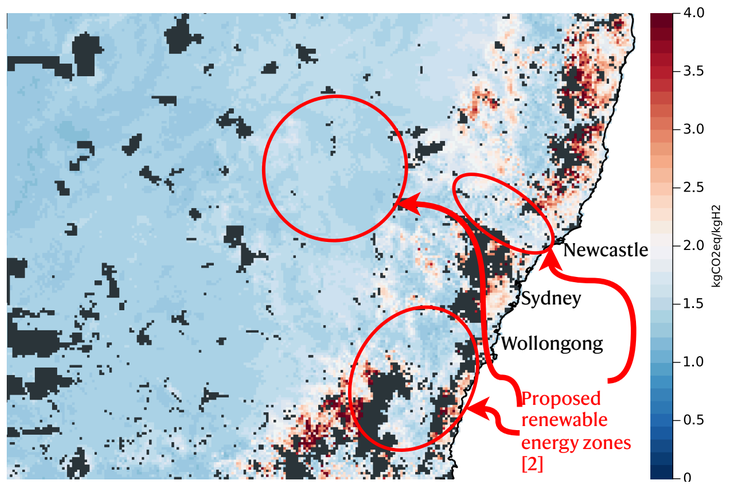




## Techno-environmental performance in NSW

- GWP in NSW with a mix of 50% solar and wind, the average impact on climate change is ~1.4kgCO2e/kgH2
- Wind power has a lower impact on climate change than solar power. Increasing the share of wind in the energy mix can reduce the specific impact). This reduces, however, the area where a PEM electrolysis plant can be implemented.

### Impact on climate change at 1km$^2$ resolution




$2\frac{A}{m^2}$ current density of operation and 60°C operating temperature; 50% solar and wind mix. Assessed for 2024 with no improvement in cell parameters. Base case scenario data can be found in Lejeune et al. 2024 [3]. Renewable energy zones are described further in ref [2].

## Discussion & Future research

- Plant operating parameters should be carefully chosen to minimise the impact on climate change.
- The geospatial techno-environmental performance of electrolytic hydrogen production in NSW renewable energy zones is relatively good (relative to the EU standard for low-emission hydrogen). However, there are potential trade-offs to consider, notably in terms of costs and location accessibility. Future work should focus on assessing the footprint of freshwater use across NSW and other impact categories.

## References

1. IEA (2021) *Net Zero by 2050 - A Roadmap for the Global Energy Sector*. Paris: IEA, p. 224. Available at: https://www.iea.org/reports/net-zero-by-2050.
2. *Renewable Energy Zone locations EnergyCo*. Available at: https://www.energyco.nsw.gov.au/renewable-energy-zones/renewable-energy-zone-locations (Accessed: 30 October 2024).
3. Lejeune, M. *et al.* (2024) 'Balancing Energy and Material Efficiency in Green Hydrogen Production via Water Electrolysis', *Procedia CIRP*, 122, pp. 958–963. Available at: https://doi.org/10.1016/j.procir.2024.01.130.

Key study behind this work

## Contact & Acknowledgements

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