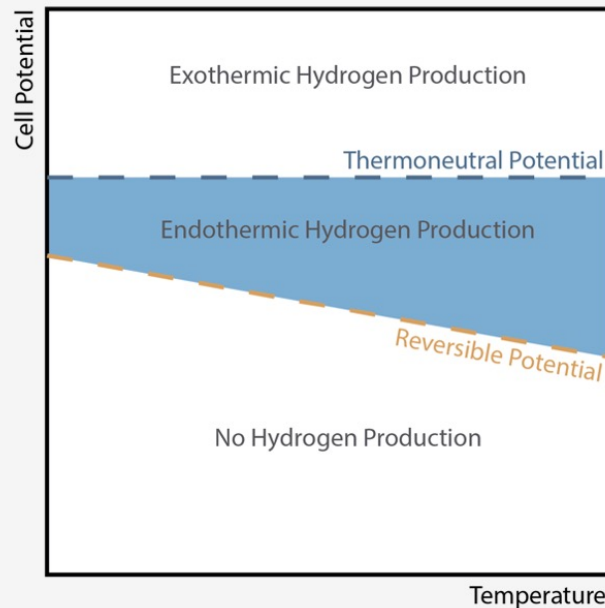


Electrolytic hydrogen at high temperature and pressure

Hydrogen Storage in Caverns 2022. Geological Society, London 14MAR2022.



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Vancouver, Canada

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<https://meridalabs.ca>



UBC: the campus as a laboratory

- UBC = small city
- GHGs down (38%) increasing population (26%)
- Risk-tolerant municipality
- Joint research & operations

#1

**Climate
Action**

Times Higher Education
Ranking

#1

**Innovation &
Industry
Partnerships**

Times Higher Education
Ranking

1st

**5G Campus
in Canada**

First 5G drone flight

**UBC Smart
Energy
District**

Hydrogen, EVs, Solar, 5G

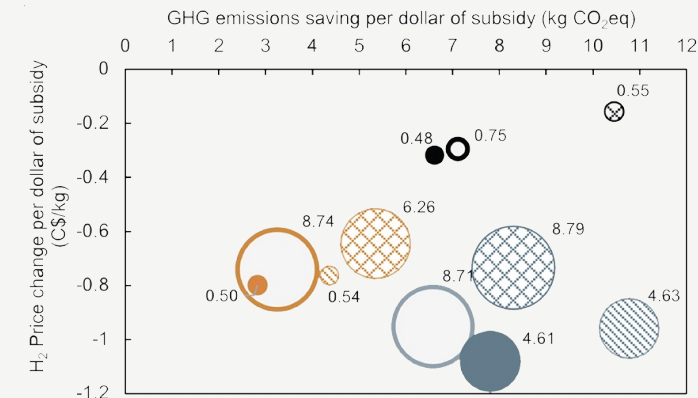
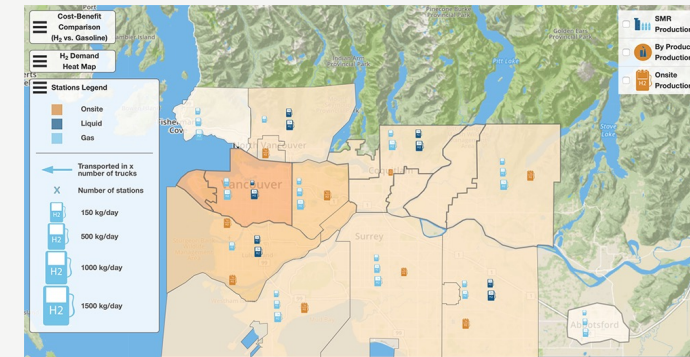
CAMPUS

CITY

MOBILITY

MéridaLabs: policy

- Techno-economic models
- Policy effectiveness
- First: transport in B.C. (light-duty)
- Other sectors (heavy- duty, pipelines)
- Other jurisdictions



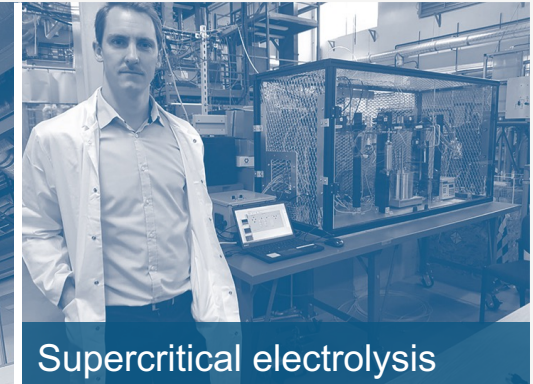
- H. Talebian, O. Herrera, W. Mérida. "Policy Effectiveness on Emissions and Cost Reduction for Hydrogen Supply Chains: The Case for British Columbia" International Journal of Hydrogen Energy, 46(1), 998-1011 (2021).
- H. Talebian, O. Herrera, W. Mérida. "[Spatial and Temporal Optimization of Hydrogen Fuel Supply Chain for Light Duty Passenger Vehicles in British Columbia.](#)" International Journal of Hydrogen Energy **44**(47), 25939-25956 (2019).

MéridaLabs: hydrogen technologies

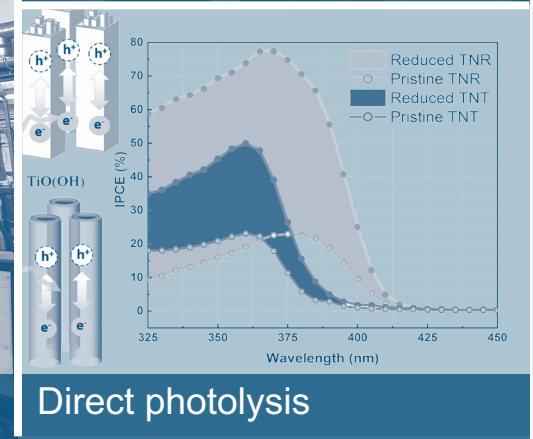
- Methane pyrolysis
- High T, P electrolysis
- Direct water photolysis
- Magnetic liquefaction



Thermal CH₄ cracking



Supercritical electrolysis



Direct photolysis

- W. Mérida , A. Sharafian, and O. Herrera (2020) “Hydrogen production from hydrocarbons without carbon dioxide emissions,” US Provisional Patent, No.: 63/026,955, Filed: May 2020.
- T. Nguyen, Z. Abdin, T. Holm, W. Mérida. “[Grid-connected electrolytic hydrogen production via large-scale water electrolysis.](#)” Energy Conversion and Management **200**, 112108 (2019).

UBC's smart energy district

Converting a city block into a smart-energy district

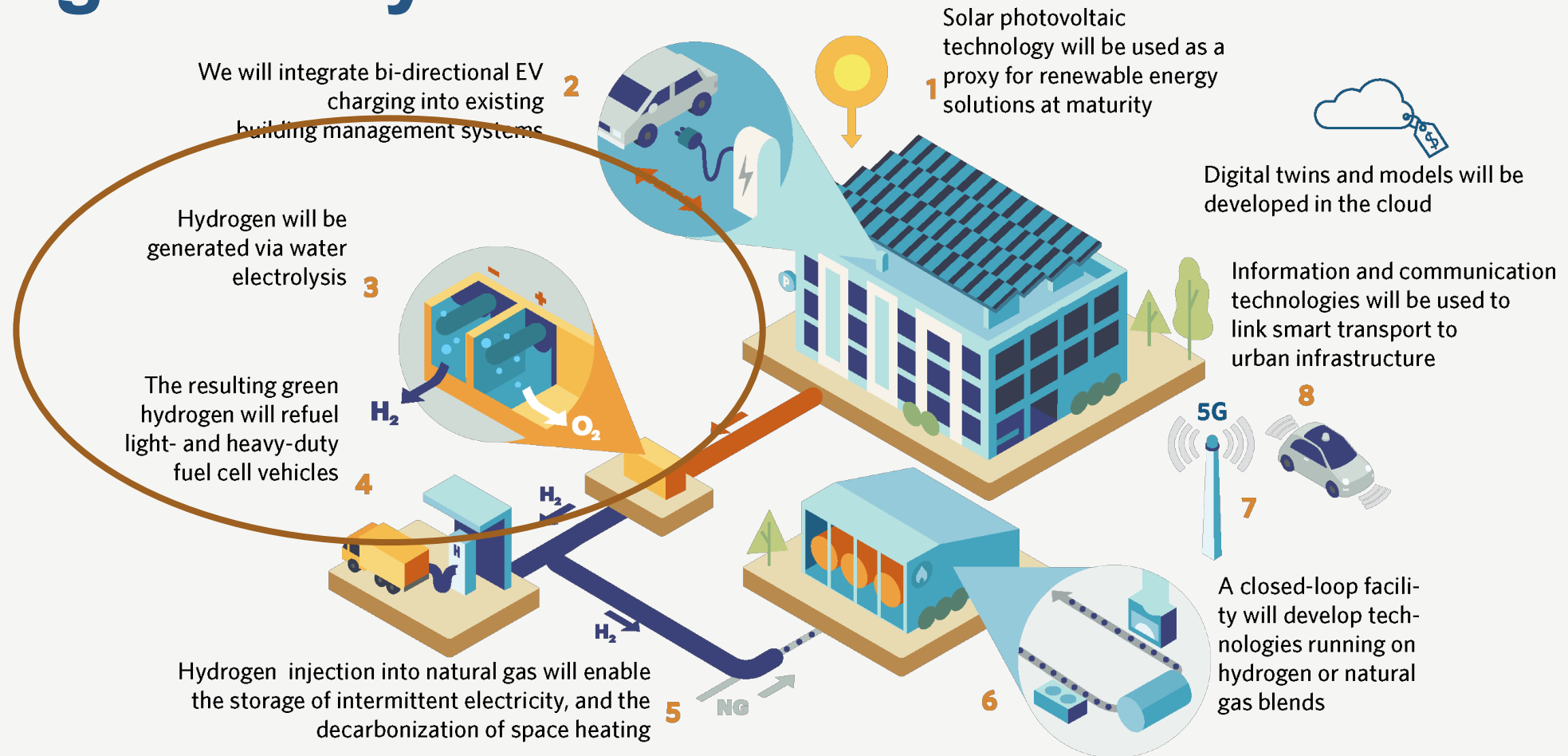
- Renewable energy
- Hydrogen hub
- Water electrolysis
- Smart transportation
- Digital twins, 5G

Under construction

<https://meridalabs.ca/research/testbed/>



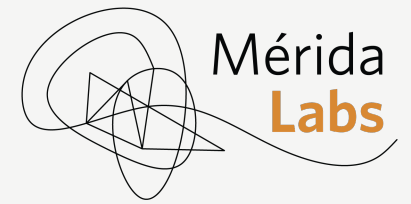
Integrated systems



<https://meridalabs.ca/research/testbed/>



THE UNIVERSITY OF BRITISH COLUMBIA



High Temperature and Pressure Water Electrolysis

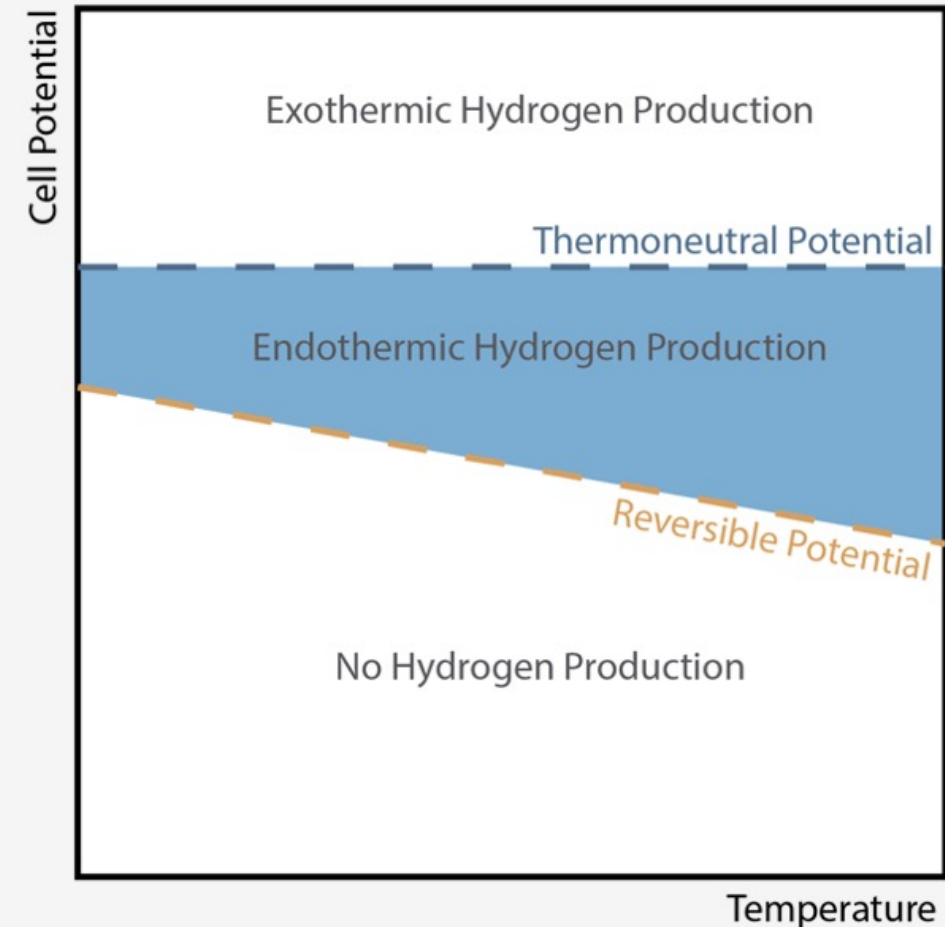


T. Holm, T Borsboom-Hanson, O. E. Herrera, and W. Mérida
Energy Conversion and Management, 237, 114106 (2021).

Why?

High-Temperature

- Increasing temperature reduces the reversible potential of water electrolysis.
- Increasing temperature increases reaction rates
- Thermal and electrical energy
- Inexpensive waste heat can be used to offset the cost of water electrolysis.



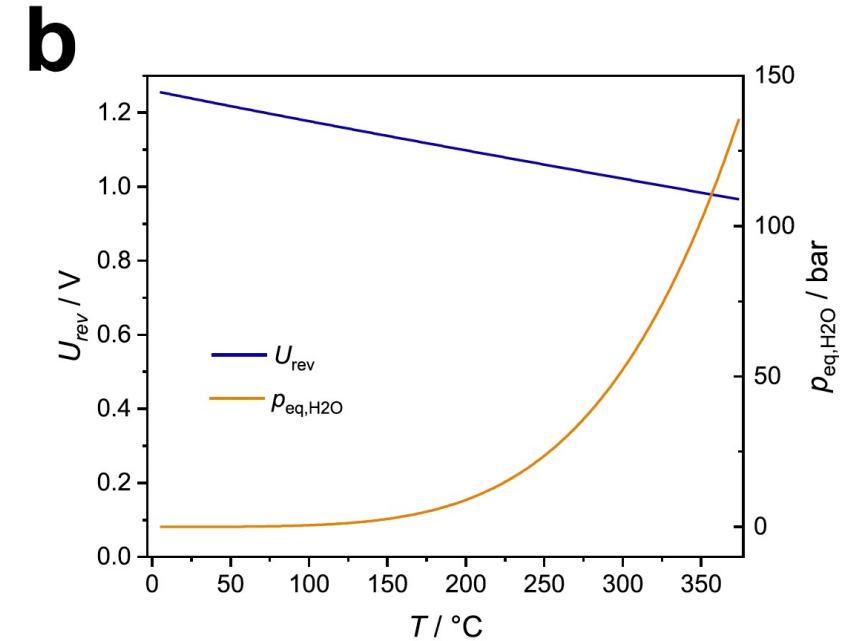
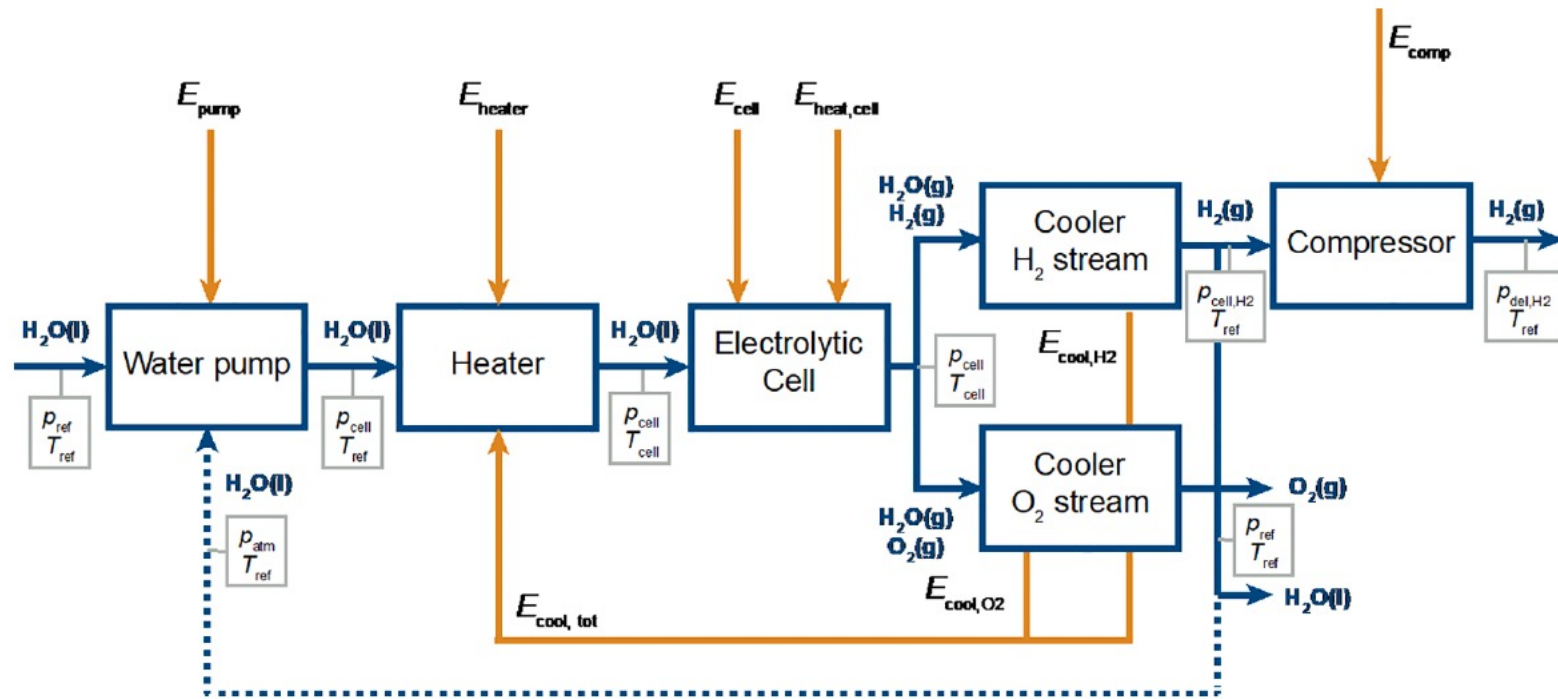
Why?

High-Pressure

- Pressurizing gas can be expensive.
- Pressurizing liquids is typically inexpensive.
 - Liquids are largely incompressible.
- By generating hydrogen at the desired pressure, we seek to reduce water electrolysis costs further.



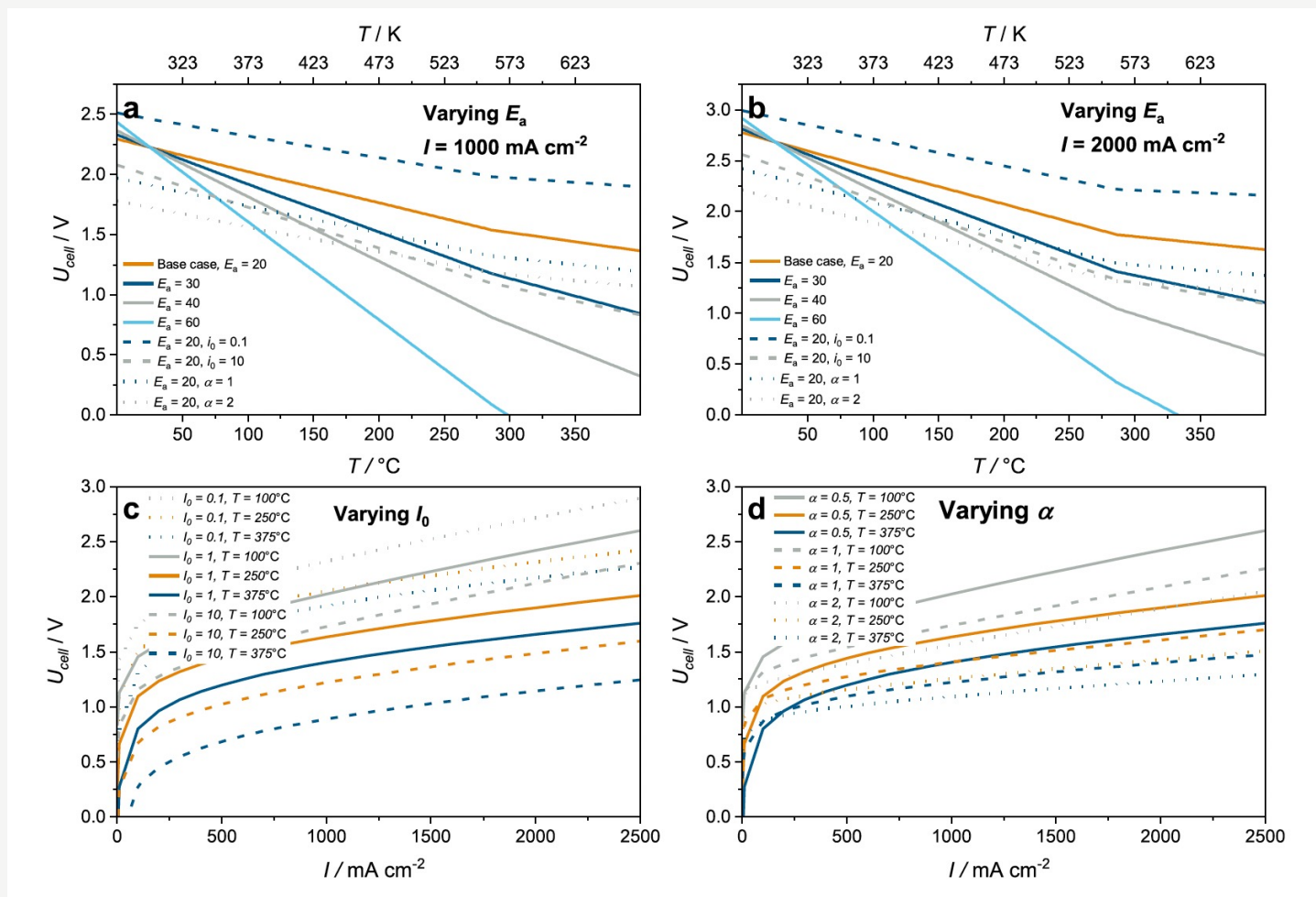
Thermodynamic model



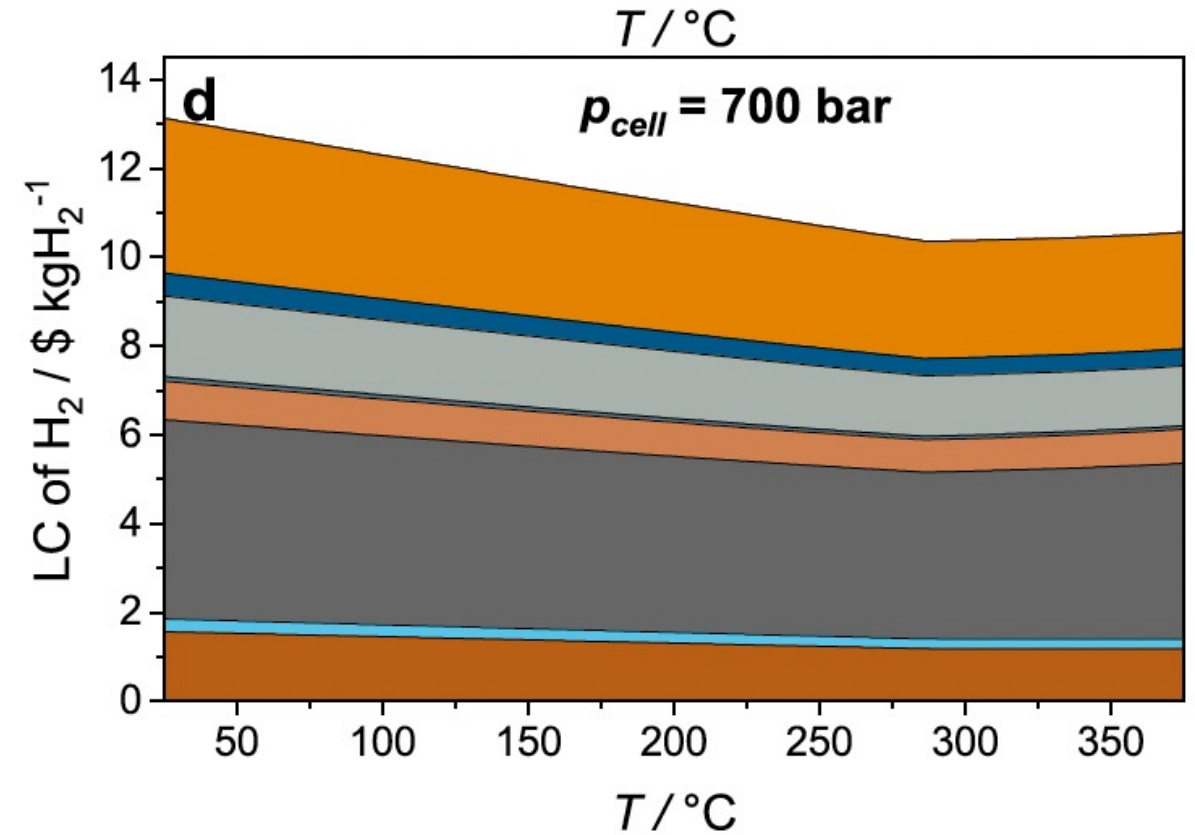
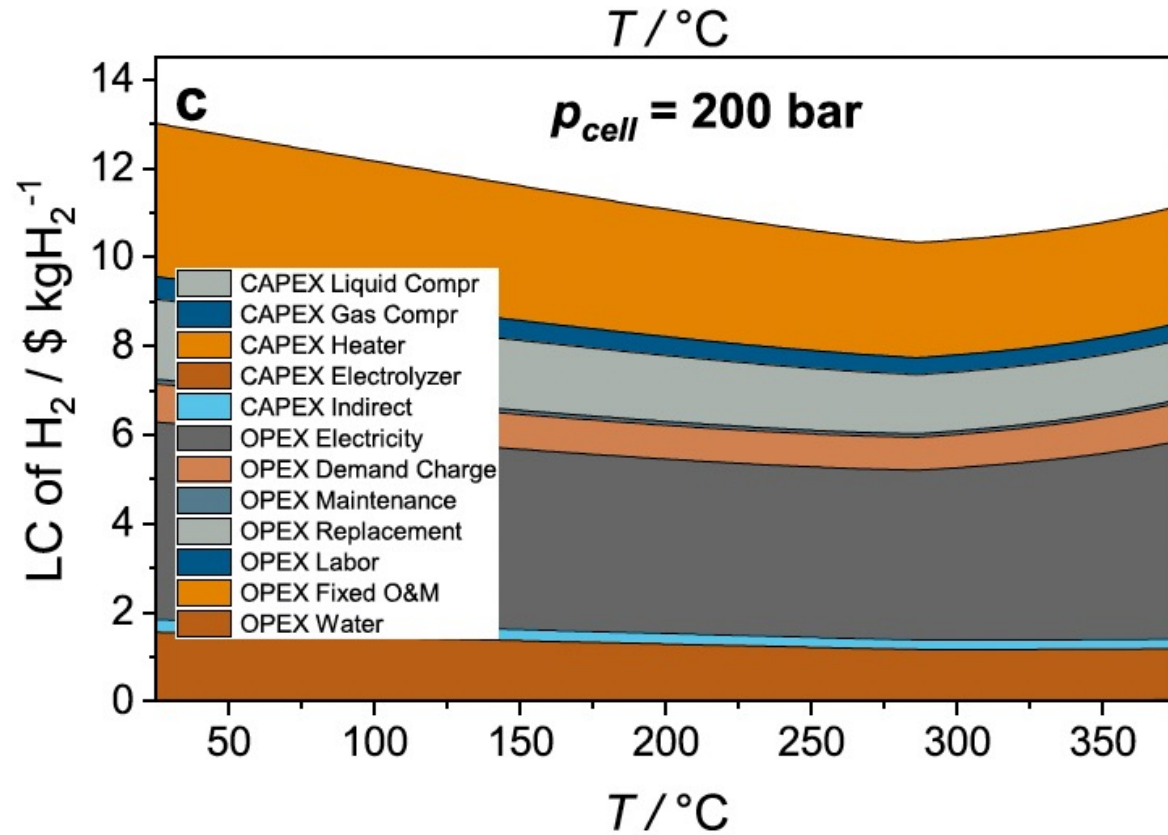
$$p_{\text{cell}} = p_{\text{eq,H}_2\text{O}}(T) + p_{\text{cell,H}_2} \quad (1)$$

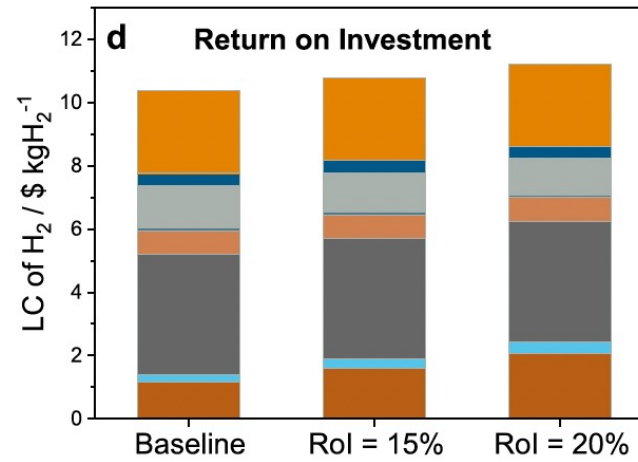
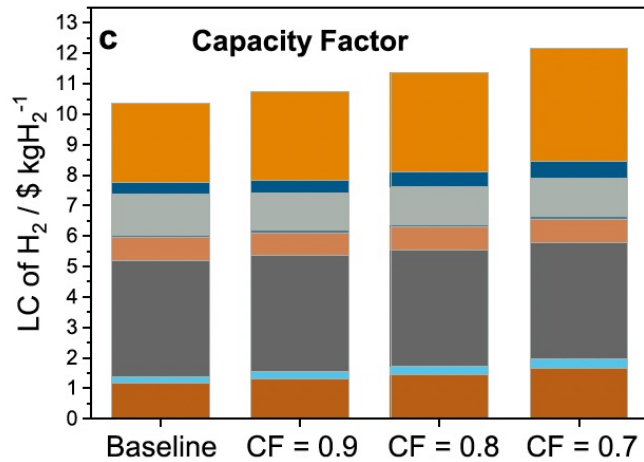
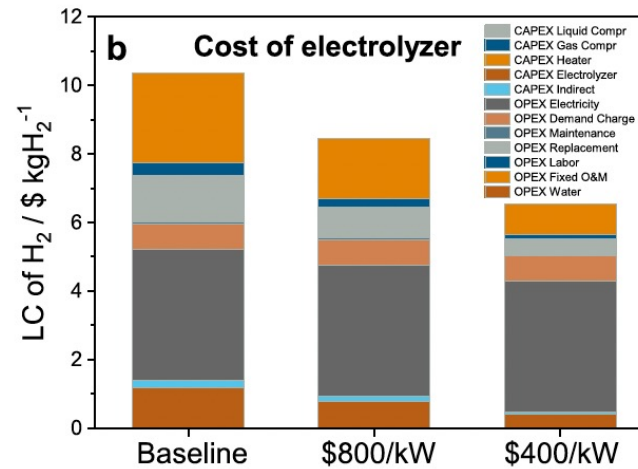
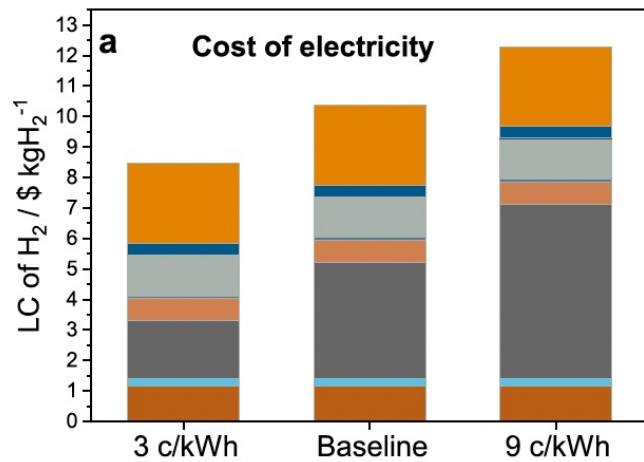
$$\log_{10}(p_{\text{eq,H}_2\text{O}}) = -0.015m - 0.0016m^2 + 2.25 \times 10^{-5}m^3 + (1 - 0.0012m + 5.60 \times 10^{-4}m^2 - 7.82 \times 10^{-6}m^3) \times \left(35.44 - \frac{3343.93}{T} - 10.9\log_{10}(T) + 0.0041T\right) \quad (2)$$

Electrochemistry model

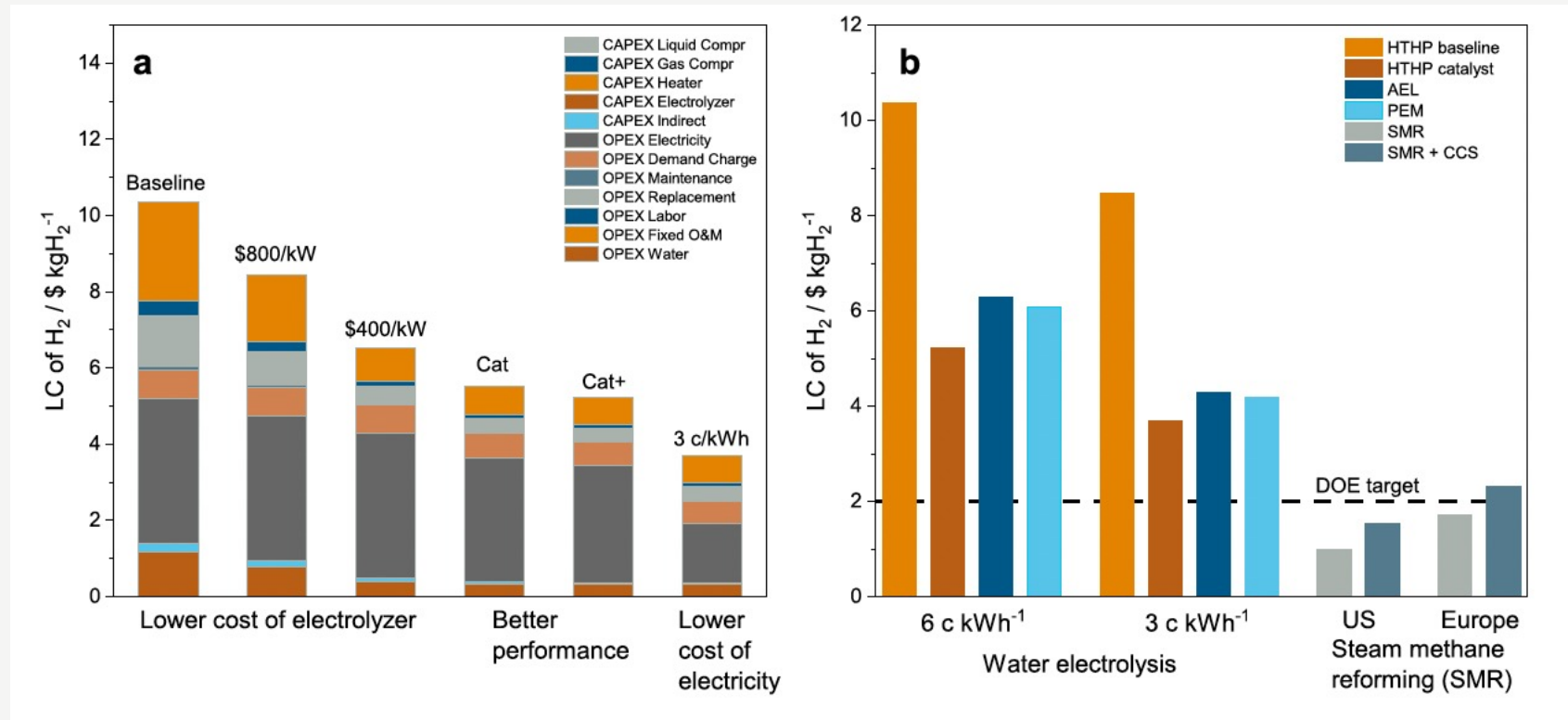


Cost/performance





Competing with fossil H2 is challenging



Future directions

- Experimental validation & supercritical conditions



- "Supercritical Water Electrolysis: A High Temperature and Pressure Framework."
Submitted to the International Journal of Hydrogen Energy (2022)



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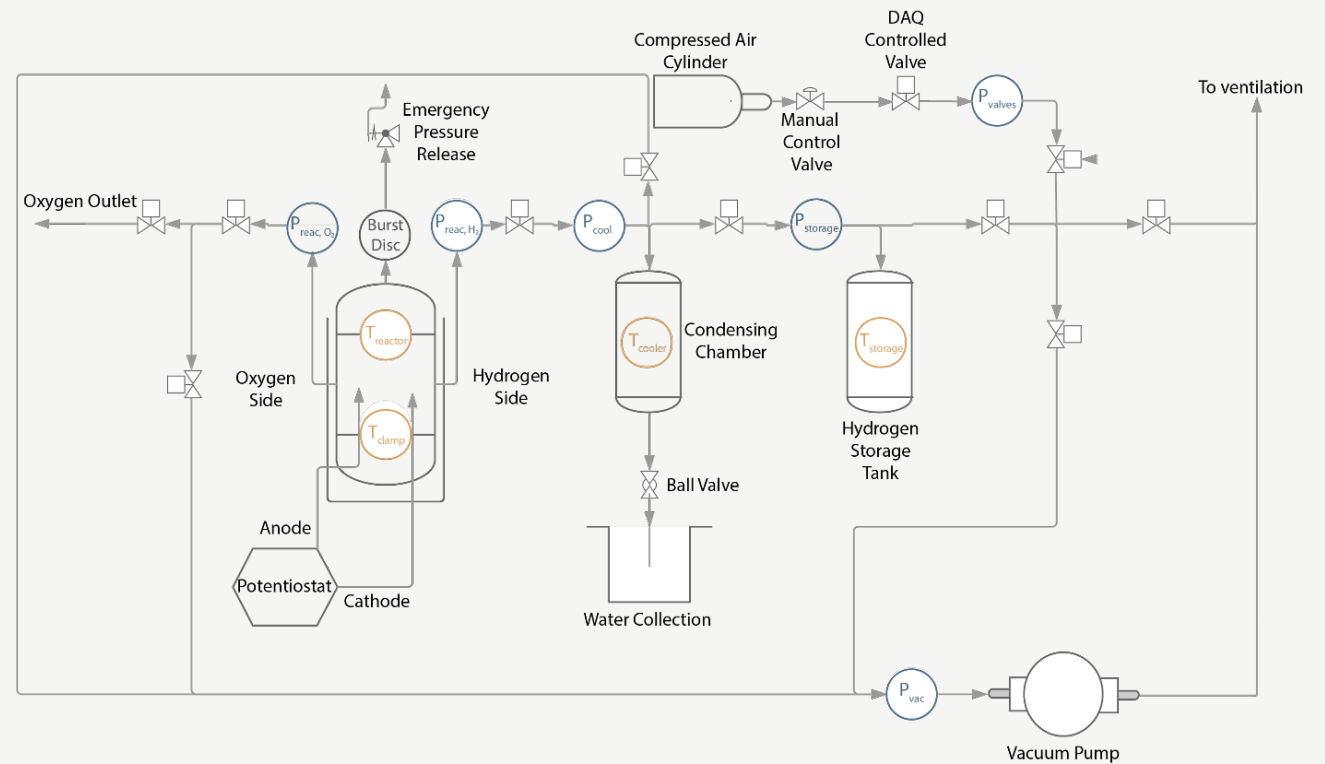
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Experimental platform

Electrolysis Framework

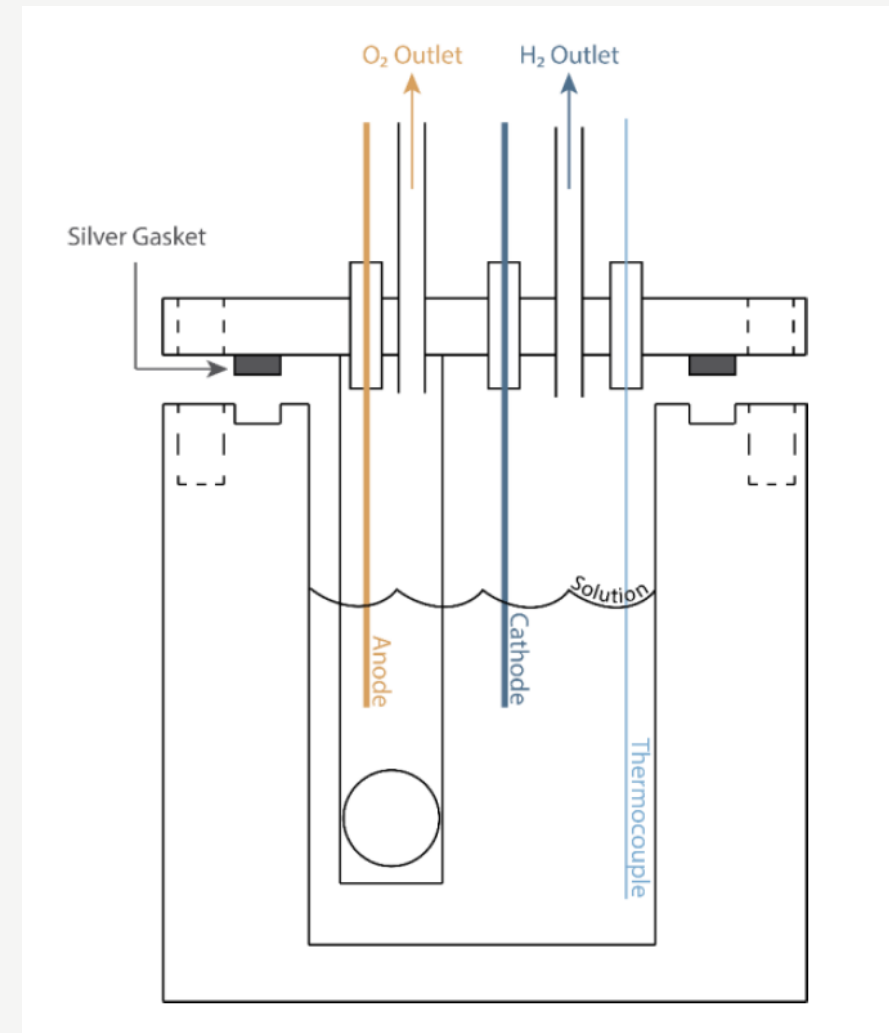
- Pressure monitoring at blue circles.
- Temperature monitoring at orange circles.
- Controlled using LabView.
- Allows for automated pressure management.



Experimental Details

Corrosion Resistant Autoclave

- Maximum temperature, 500 °C.
- Maximum pressure, 350 bar.
 - The saturation vapor pressure of water reaches this at around 410 °C.
- Built using Hastelloy C22, a nickel-based alloy designed for corrosion resistance in alkaline solutions.



Targets and conclusions

- Improve catalysts (2000 mA cm^{-2} at 1.66 V) → CAPEX of electrolyser can be 25% higher than AEL and PEM systems
- Direct pressurization above 200 bar
- Cell design $< \text{US\$}500 \text{ kW}^{-1}$
- Minimum energy consumption and levelized cost at 270-310 Celsius
- Heating costs and high vapour pressure detrimental at 290 Celsius
- Direct production of high-pressure hydrogen always desirable compared to low-pressure production with pneumatic compression
- All electrolytic hydrogen production pathways have higher costs than DOE targets (even for very low electricity costs)



Thank you!
Merci!



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