Integrated Systems for Renewable Ammonia and Urea Production

Ammonia Energy Association Conference

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Agenda

1. The Opportunity
2. Decentralised Renewable Ammonia Production: Airmmonia Technology
3. Beyond Renewable Ammonia: Urea fixation

The Opportunity

- Stakeholder consultation during development of HySupply State of Play and Roadmapping report clearly indicate a large role for renewable ammonia as energy vector
- Considerable domestic interest revealed through NSW Power to X Pre-Feasibility Study, setting up NSW Decarbonisation Innovation Hub.

HySupply is a two-year feasibility study between Australia and Germany to explore the export opportunities for hydrogen and its derivatives

HySupply Background

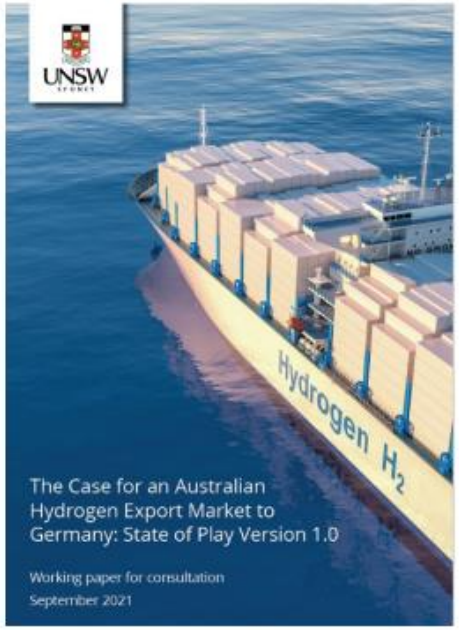
Australia's Department of Foreign Affairs and Trade (DFAT) and Department of Industry, Science, Energy and Resources (DISER) and Germany's Federal Ministry of Education and Research (BMBF) have jointly funded the HySupply Project, a two-year feasibility study to investigate the export of hydrogen/hydrogen-derivatives from Australia to Germany. The University of New South Wales (UNSW) has been appointed by DFAT and DISER as the project lead for HySupply Australia. The broader project however is being delivered alongside, HySupply Germany, led by BDI and Acatech.

State of Play (SoP) – Consultation Paper

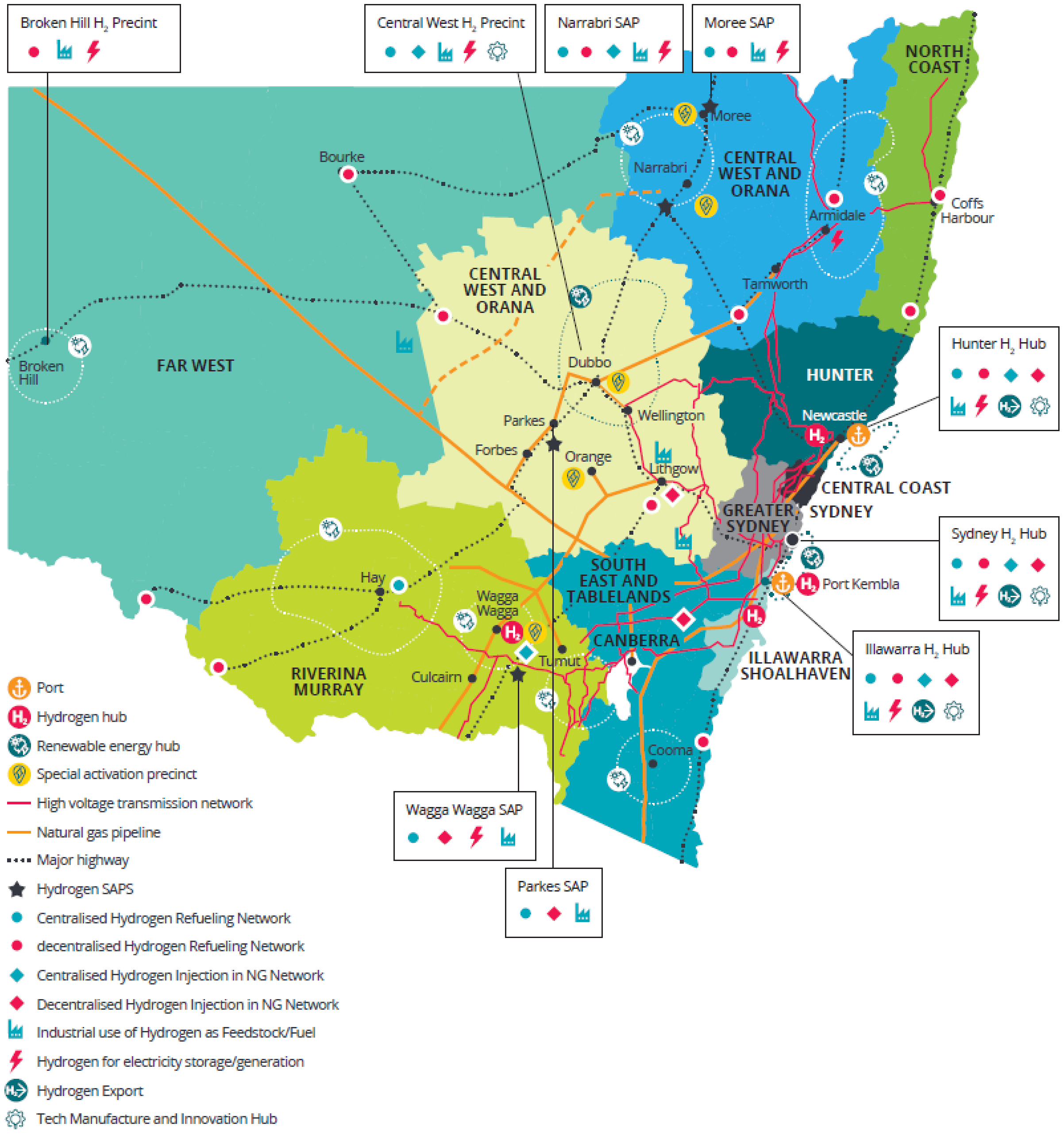
The SoP report is the first deliverable that was released by HySupply Australia. The report assesses Australia's export potential for hydrogen and its derivatives. This is done to provide both German and Australian stakeholders with an overview of how Australia's well established and globally leading role in conventional energy exports, and world-class renewables resources, can be leveraged for the development of a new export energy value chain assisting other countries such as Germany to achieve their decarbonisation objectives. The report is also intended to enhance the shared understanding of industry, Government and private sectors across Australia and Germany.

HySupply Open Source Tools

As part of the project, HySupply Australia developed a cost tools that allows for both real time simulation of hydrogen generation and its associated costs. A shipping analysis tool has also been developed to model the cost of shipping hydrogen (as liquid hydrogen (LH2) and hydrogen carriers (ammonia, methanol, methane (LNG) and LOHC (as toluene/methylcyclohexane (TOL/MCH)). See **Appendix** for more details.



Daiyan*, MacGill, Amal. The Case for an Australian Hydrogen Export Market to Germany: State of Play. 2021.



Case for Direct Decentralised Systems

- Decentralised on-site production (not necessarily microhub)
- Green fertilizer
- Diesel substitute in regional areas
- Compatibility with intermittent renewable energy

Daiyan*, Amal *et al.* NSW Power to X Feasibility Study. In Progress.

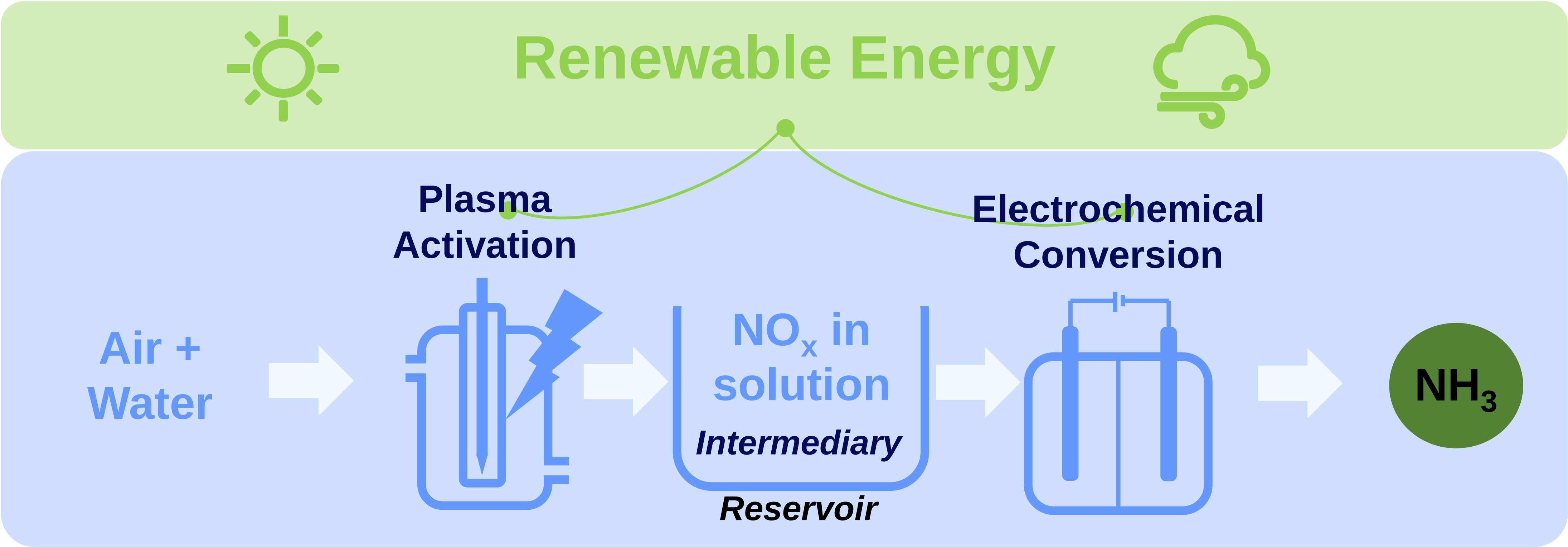
Airmmonia Technology

Ambient temperature and pressure

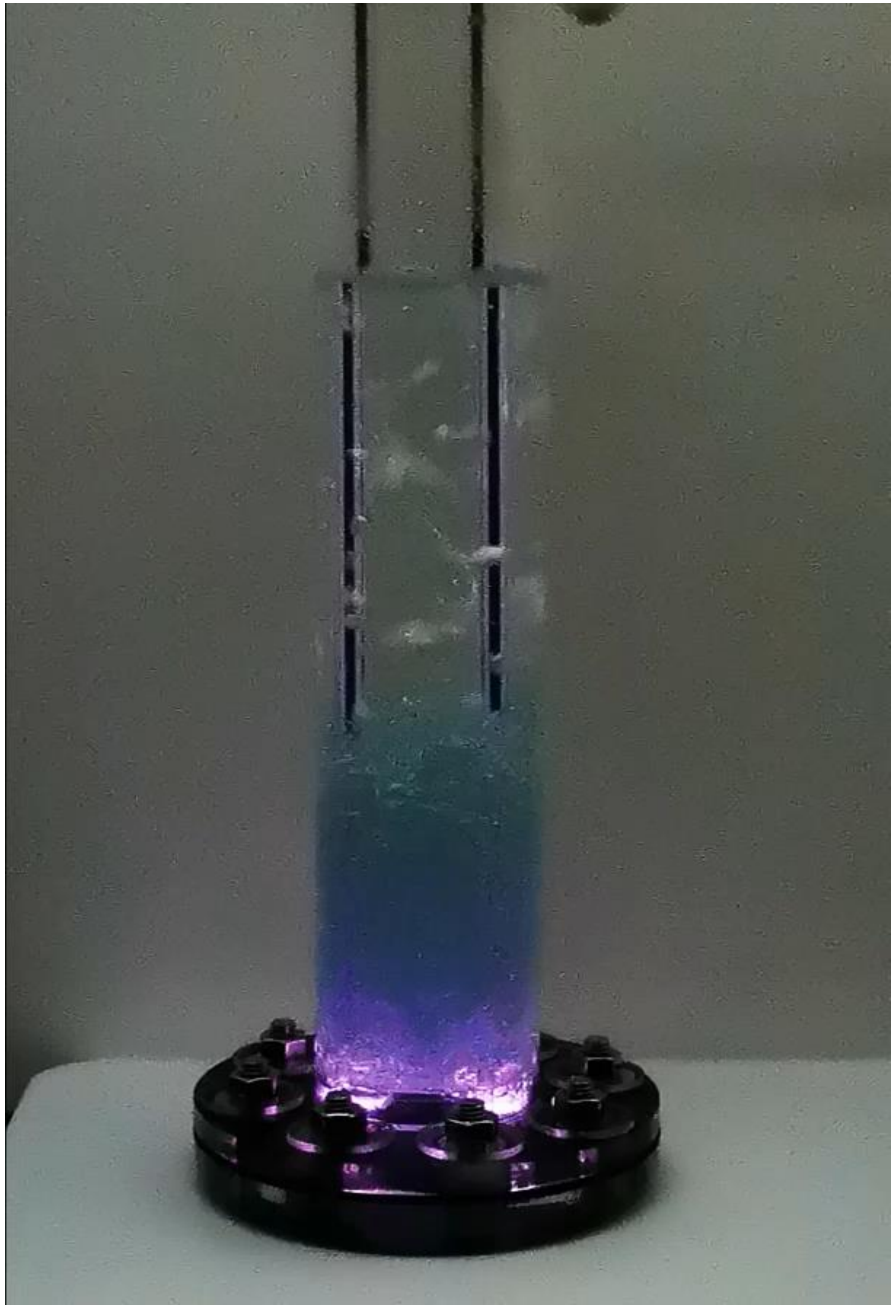
Transforming only air and water

Compatible with Variable Renewable Energy (VRE)

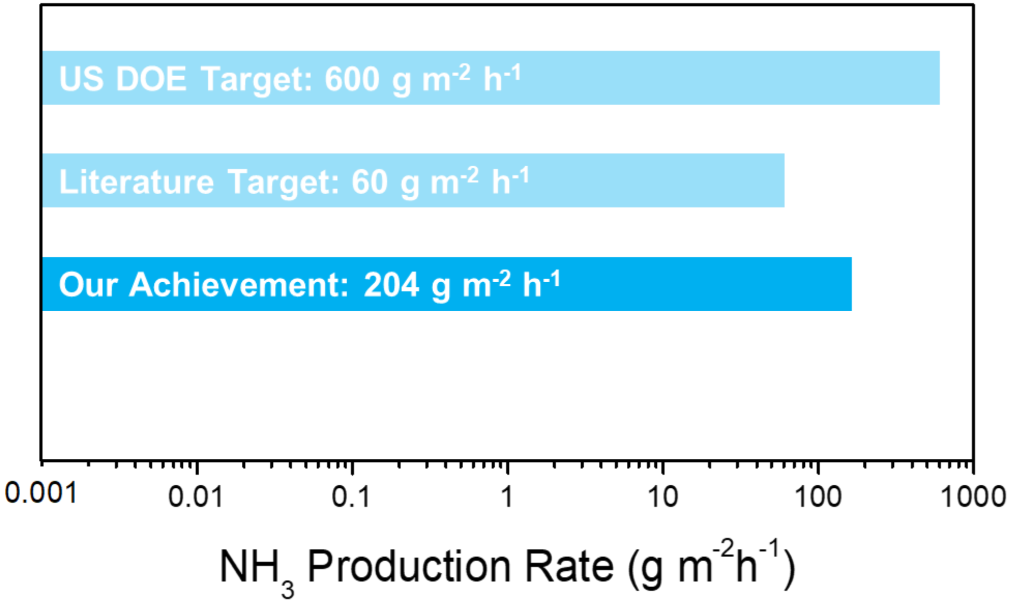
Hybrid Plasma-Electrolysis



Optimisation and Scaleup

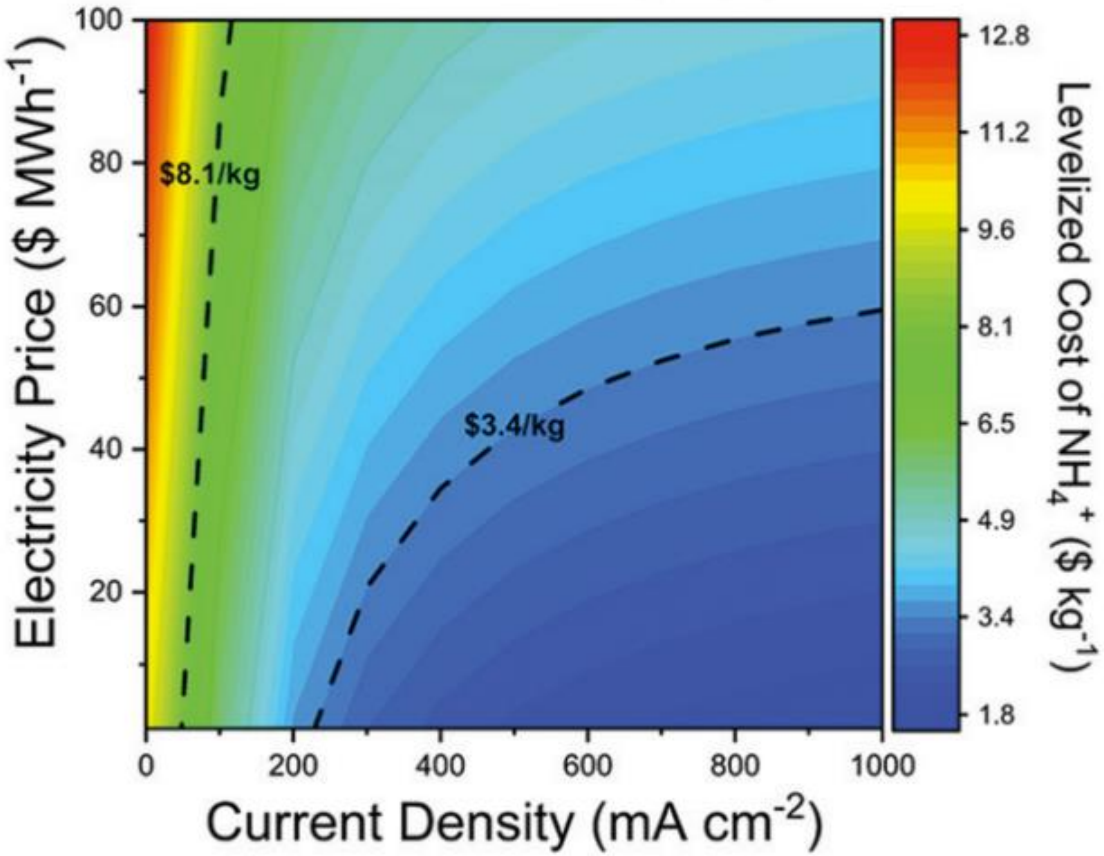


- Initial yield of 42.1 nmol/cm^2.s requiring ~250 kWh/kg$_{NH3}$
- Catalyst/electrolyser design and optimization allows attaining production rate to 333.33 nmol/cm^2.s requiring ~60 kWh/kg$_{NH3}$

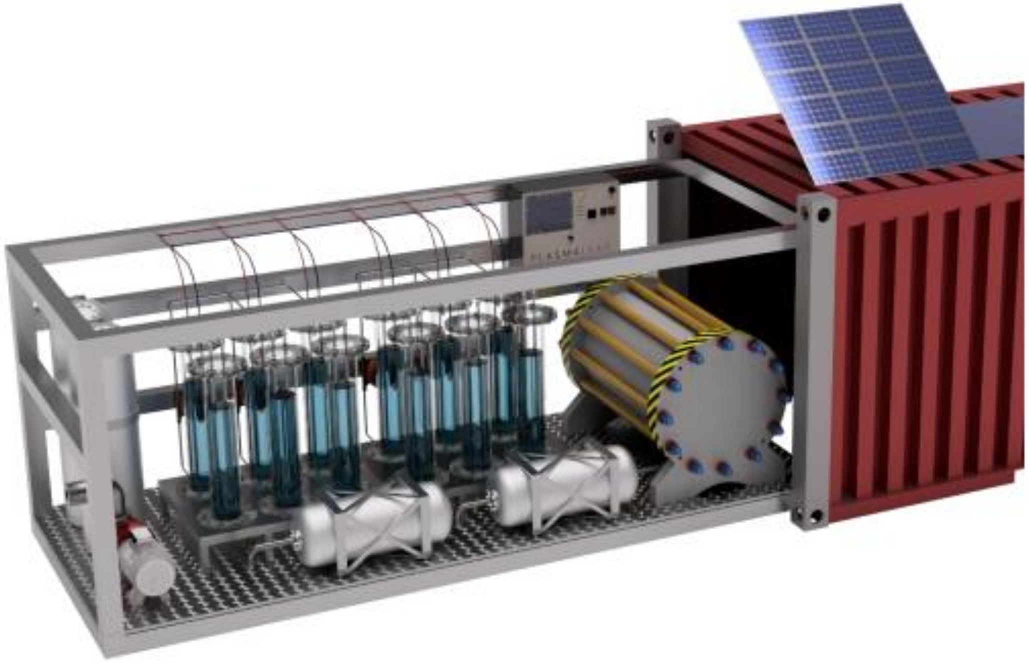


1. PCT/AU2022/050309
2. PCT/AU2021/051172
3. Daiyan, Lovell, Amal et al., Energy Environ. Sci., 2021, DOI: 10.1039/D1EE00594D.
4. Sun, Daiyan, Lovell, Jalili, Amal et.al., *Energy Environ. Sci.*, 2021,14, 865-872

Importance of System Design



- Utilising low-loading catalysts
- Transition away from critical minerals



Beyond Ammonia: Urea

Why Urea?

- Compared to alternative nitrogenous fertilizers (such as ammonia), urea offers a higher N content, ease and safety of handling, and lower transportation costs
- Global uncertainty and inflation, supply chain disruptions, and rising food and fuel prices have caused the price of urea to significantly increase over recent years, and has threatened Australia’s supply of urea
- As a global food bowl, it is imperative that Australia ensures a stable and reliable supply chain for urea


The Washington Post
Democracy Dies in Darkness

ECONOMY

Fertilizer crisis delivers profits and pain as Ukraine fallout broadens

‘It’s brutal. Farmers aren’t buying what they need; they are buying what they can afford,’ one expert said

Electrochemical Conversion of Waste CO_2 and NO_x to Urea

Closing the carbon and nitrate cycles

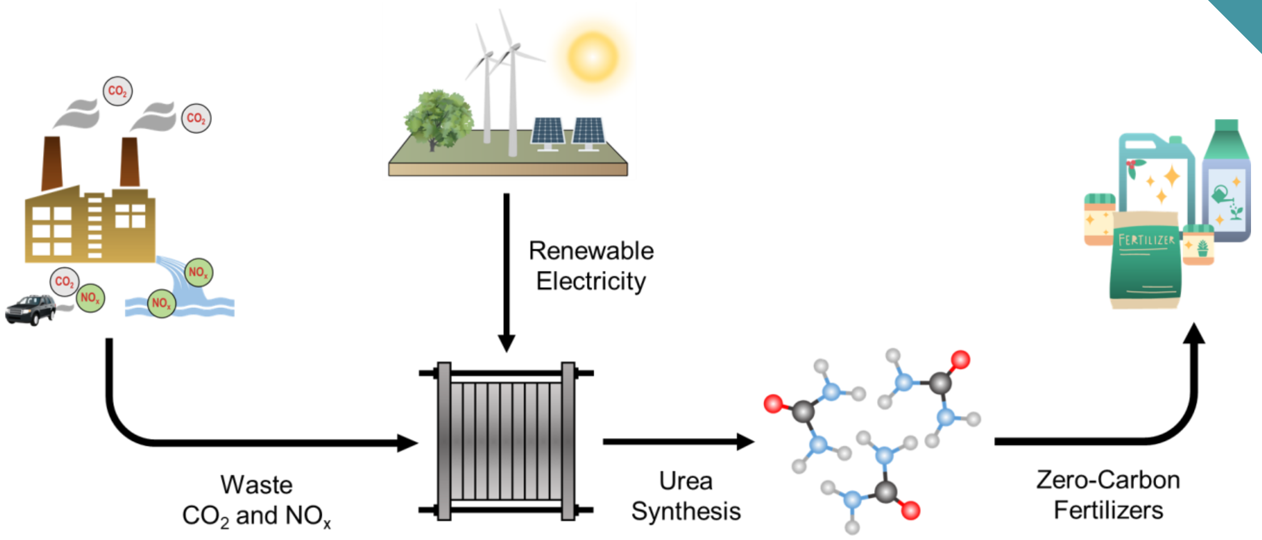
A promising route towards decarbonisation and a circular economy

CO_2RR and NO_xRR

Simultaneous electrochemical reduction of CO_2 (CO_2RR) and nitrates (NO_xRR) can be employed to produce urea (Renewable Power-to-X)

An active electrocatalyst

This reaction pathway is non-trivial due to the range of competing reactions leading to various gas and liquid products. As such, an integral system component is an electrocatalyst that can produce urea at acceptable yields whilst minimising the production of competing liquid products



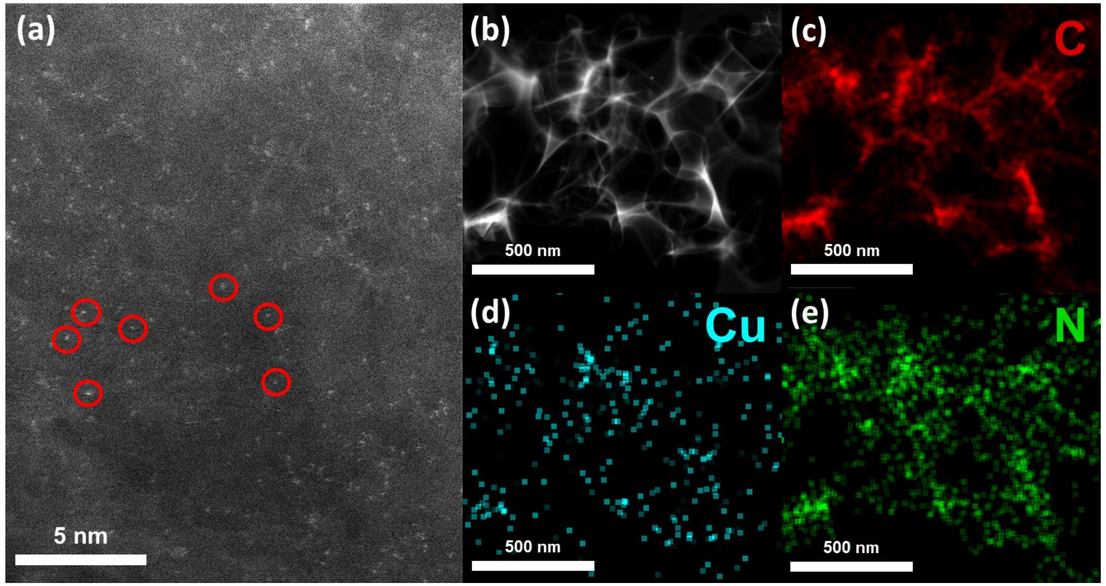
Cu-N-C Single Atom Catalysts: Synthesis and Characterisation

Synthesis

The catalysts are synthesised through the combination of carbon, nitrogen and Cu precursors, which are then freeze-dried and annealed at various temperatures (800, 900, and 1000 °C), to yield unique coordination structures

Single Atoms

High-resolution scanning transmission electron microscopy allows visualisation of the individually-isolated Cu atoms (as bright spots throughout the carbon matrix). The Cu single atoms are coordinated via the N dopant, which can be gradually removed through higher annealing temperatures



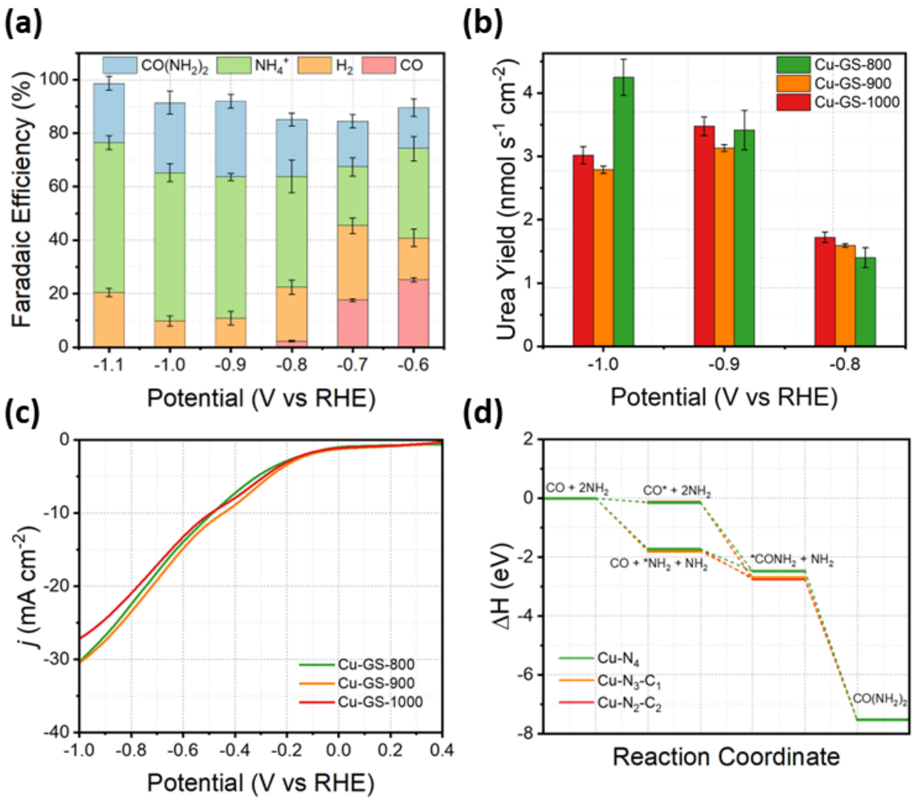
Performance for Electrochemical Urea Synthesis

SACs adsorb CO_2 and NO_3^-

The Cu SACs show the ability to adsorb both CO_2 and NO_3^-, necessary for C-N coupling reactions required to produce urea

Cu-N_4 sites

We find that the maximum FE_{Urea} of 28% is achieved with Cu-GS-800 at −0.9 V versus RHE, whilst Cu-GS- 900 and Cu-GS-1000 achieve an FE_{Urea} of 25% and 23% at the same potential, respectively. DFT calculations indicate that the formation of the *COOH intermediate could be a rate-determining step for both CO_2RR and urea production, explaining the superior performance of Cu-N_4 sites for both reactions



Leverett, Simonov, Hocking*,Daiyan*, Amal*. Advanced Energy Materials 2022, 2201500. https://doi.org/10.1002/AENM.202201500.

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ARENA

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University Collaborators

The University of Sydney

Monash University

Swinburne University of Technology

Australian National University

And our 65 industry partners from ARC Training Centre for The Global Hydrogen Economy, NSW Powerfuels including hydrogen network and Decarbonisation Innovation Hub

Details: https://www.globh2e.org.au/

Thank you

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UNSW Sydney

GlobH2E
ARC Industrial Transformation Training Centre for the Global Hydrogen Economy