FUTURE energy

Program Book

NSW NET-ZERO NEXT-GEN ASSEMBLY 2024

UNSW SYDNEY

THE UNIVERSITY OF SYDNEY
Net Zero Institute

Powerfuels including Hydrogen Network
DECARB HUB

GlobH2E
ARC Industrial Transformation Training Centre for the Global Hydrogen Economy

PROGRAM

NSW Net Zero Next Gen Assembly 2024 – Monday, 18 November 2024

Venue: Colombo Theatre

11.00 - 11.30	**Arrival and registration for NSW NetZeroNextGen Assembly and Morning Tea**
11.30 - 11.45	**Welcome and Opening Address** Welcome (Dr Emma Lovell, Co-Chairs of EF5 and NZNG) Opening address (Professor Maurice Pagnucco, Deputy Dean of Engineering, UNSW) and Prof Deanna D'Alessandro, Director of NZI, USydney)
11.45 - 12.45	**Panel Discussion:** NetZero – Now and in the future
	Panel discussion: Net Zero: How do we reach our 2050 emissions targets, sustainably? Panellist: Will Howard (Climate Change Authority), A/Prof Nicholas Lawson (USydney), Dr Jessica Allen (Univ of Newcastle). Moderator: Dr Emma Lovell
12.45 - 13.45	**Lunch and POSTER SESSION.**
	NZNG Assembly – Session 1 Chair: Dr Shuying Wu (USyd)
13.45 - 14.00	Our eyes now and the next generation (Dr Chris Hodge, USyd)
14.15 - 14.30	Technology development challenges outside the laboratory: Considering the role of research in decarbonisation (Dr Jessica Allen, Univ of Newcastle)
14.30 -14.45	Co-Designing Policy for a Sustainable NSW Construction Industry (Alan Murray, UTS)
14.45 - 15.00	Reuse, reduce, recycle: How reversible flocculants take us a step forward in decarbonisation of the water industry (Dr Naras Rao, UNSW)
15.00 - 15.30	**Afternoon Tea & POSTER SESSION**
	NZNG Assembly – Session 2 Chair: George O'Connell (UNSW Sydney)
15.30 - 15.45	Plasma, Magnetism, and Polyphosphates (Dr Joy Jiang, USyd)
15.45 - 16.00	Indonesia can become a major sustainable aviation fuel producer (Dr Denny Gunawan, UNSW)
16.00 - 16.15	Decarbonizing Australia: Pathways to a Sustainable and Affordable Net-Zero Future (Dr Mengyu Li, USyd)
16.15 - 16.30	Zinc Batteries for Sustainable Energy Storage (Dr Zengxia Pei, USyd)
16.30 - 16.45	Value-Added Upcycling of Waste Solar Panels (Dr Rasoul Khayyam Nekouei, UNSW)
16.45 - 17.00	Biopolymer Nanocomposites for Wearable Electronics (Dr Shuying Wu, USyd)
17.00 - 18.30	**NetZeroNextGen Networking drinks and POSTER SESSION.** **Poster Award presentation** (Dr Emma Lovell, UNSW) Best Poster Prize for Fundamental Research on Decarbonisation (Chem Eng) Best Poster Prize for Applied and Translational Research for Sustainable Energy Transition (GlobH2E) People's Choice Award (PFHN)

NSW Net Zero Next Gen Assembly Poster Presentation

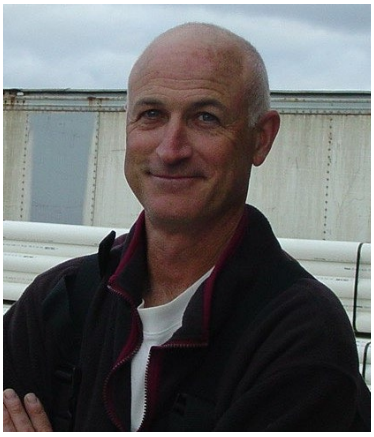
Co-Chair of NSW Net Zero Next Gen Assembly 2024

Dr Emma Lovell is a Senior Lecturer and ARC DECRA Fellow in the School of Chemical Engineering at UNSW Sydney. Her research, undertaken in the Particles and Catalysis (PartCat) Research Group focuses on developing novel catalysts for a range of applications; with a particular focus on energy and environmental catalysis. Emma completed her PhD in 2016 at UNSW developing catalysts for carbon dioxide conversion.

Co-Chair of NSW Net Zero Next Gen Assembly 2024

Dr Jingjing You is a Senior Lecturer of Biomedicine in the School of Medical Sciences at the University of Sydney. Her research aims to develop effective treatments for wound healing, including eye and brain injuries.

As well as academic successes, Jing’s inventions have led to 3 commercial products, including collagen bioinks used to make human cornea. She also established a university-based collagen production facility.



Panellist - Net Zero: How do we reach our 2050 emissions targets, sustainably?

Dr Will Howard is Lead Scientist at the Commonwealth Government Climate Change Authority, working across climate science and adaptation, climate policy, negative emissions and other issues.
He received his Ph.D in Geological Sciences from Brown University in the USA. He worked at the Office of the Chief Scientist in Canberra from 2010 to 2017, serving as Head of Science there in 2016-17
He is a member of the National Committee for Earth System Science.
He continues to research marine climate change, with particular emphasis on ocean acidification and its impacts on the past, current, and future ocean, through affiliation at Australian National University.

Panellist - Net Zero: How do we reach our 2050 emissions targets, sustainably?

Associate Professor Nick Lawson joined the Department of Aeronautical Engineering at the University of Sydney in Oct21, after 22 years in the School of Aerospace at Cranfield University. Over this period, he was Head of National Flying Laboratory Centre for 5 years and held a Chair in Aerodynamics and Airborne Measurement. Nick holds a Commercial Pilots Licence, with over 2500 hours of flying experience in the Cranfield Jetstream 31 flying lab, including flight trials in the BAE Systems Flying Test Bed. He was also previously an instructor in the Bulldog and Slingsby light aircraft and is a Chartered Engineer, a Fellow of the Royal Aeronautical Society and a member of the Society of Flight Test Engineers. He continues to fly regularly in Australia for the University of Sydney.

Panellist – Net Zero: How do we reach our 2050 emissions targets, sustainably
&
Keynote Speaker: **Technology development challenges outside the laboratory: Considering the role of research in decarbonization**

Dr Jessica Allen is a Senior Lecturer and principal researcher in the discipline of Chemical Engineering in the University's School of Engineering. Teaching awards attest to the esteem in which she is held by her students and colleagues, and numerous accolades including a 2021 DECRA Fellowship and being named a 2021 Superstar of STEM showcase her tremendous research capacity and achievements. Dr Jessica Allen has also been recognised with a NSW 2023 Young Tall Poppy Science Award for her outstanding contribution to science communication.

Keynote Speaker: **Our eyes now and the next generation**

Dr Chris Hodge is the National Clinical Research Coordinator with Vision Eye Institute, a privately-owned group of >20 ophthalmology clinics and day surgeries. Additionally, he holds positions as Senior Research Fellow, School of Medical Sciences and Clinical Senior Lecturer, Discipline of Ophthalmology. He has published > 130 peer-reviewed articles and textbook chapters across ophthalmology and eye health.
He is a member of the Net Zero Initiative at University of Sydney.

Keynote Speaker: Co-Designing Policy for a Sustainable NSW Construction Industry

Alan Murray is the CEO of Circular Economy Partners and an industry professional with a strong focus on implementing digital technology innovations to drive sustainability. With a background in key roles across NSW Health and Transport for NSW, Alan brings a wealth of experience in navigating complex industries and advancing impactful initiatives. He is currently pursuing a PhD with UTS supported by the NSW Building Commission and focused on designing a transformative circular economy model tailored for the NSW construction sector, aiming to redefine industry practices and promote sustainable growth. Alan's work combines a commitment to environmental stewardship with a practical approach to innovation, making him a leader in the field of circular economy advancement.

Keynote Speaker: Reuse, reduce, recycle: How reversible flocculants take us a step forward in decarbonisation of the water industry

Dr Naras Rao is an ARC DECRA Fellow at the EnviroLabs in the School of Chemical Engineering at UNSW. He graduated with an S.B. in Chemical Engineering (India/USA at UW-Madison) and obtained his Ph.D. in Chemical Engineering at The University of New South Wales, Sydney, in 2018. He then held positions as a Research Associate and Senior Research Associate at UNSW before moving to Belgium, where he became a Marie Curie Fellow at KU Leuven. Naras' research interests focus on improving resource management and reuse and are tailored towards optimising particle separation in the water treatment, mining and biotechnology fields. He has received over $1.5 million in competitive grant funding for major research projects as lead Chief Investigator from premier Australian and European agencies and the Australian water industry. His work has been published in peer-reviewed journals and industry technical reports, particularly on polymer and nanomaterial design for efficient cyanobacteria separation, the effects of climate change on catchment dynamics, and advancements in monitoring technologies for water contaminants. Naras has also played key roles in fostering industry-academia collaboration, chairing the Industry-Academia Partnership Committee at KU Leuven's YouReCa Center and serving as a Marie Curie Ambassador for the BeNeLux Young Water Professionals Association.

Keynote Speaker: Plasma, Magnetism, and Polyphosphates

Dr Joy Jiang completed her Ph.D. in Chemistry (Warr group) from USyd, developing nanomaterials and functional ionic solvents. She then did a postdoc in the Department of Chemistry and Chemical Biology (Whitesides group) and Astrophysics (Sasselov group) at Harvard University, where she worked at the intersection of chemistry, materials science, and engineering, as well as exploring the chemical origin of life. Joy returned to USyd in 2024, as a Sydney Horizon Fellow and group leader in the School of Chemistry.

Keynote Speaker: Indonesia can become a major sustainable aviation fuel producer

Dr Denny Gunawan is a Postdoctoral Researcher of the ARC TC for the Global Hydrogen Economy based in the School of Chemical Engineering, UNSW Sydney. He is passionate about developing a practical artificial photosynthesis process, which mimics natural photosynthesis, to convert sunlight into green chemical fuels, contributing to global decarbonisation efforts. Apart from research, he has also been active in advocating the critical role of renewable energy to reach net-zero emissions. He wrote several opinion pieces on topics revolving around energy transition issues published in popular media outlets, such as The Conversation and The Jakarta Post.

Keynote Speaker: Decarbonizing Australia: Pathways to a Sustainable and Affordable Net-Zero Future

Dr Mengyu Li is a Horizon Fellow, ARC DECRA Fellow, Senior Lecturer at Integrated Sustainability Analysis, the School of Physics, the University of Sydney. Mengyu has an interdisciplinary background in engineering and sustainability. Mengyu's research focuses on quantitative sustainability assessment of the interactions of societies and economies with ecosystems and resources at local, national, and global scales. Mengyu develops and applies concepts and research involving interdisciplinary perspectives from economics, engineering, mathematics, environmental and social science with the ultimate aim to assure both human and planetary well-being. Mengyu devises methodologies and conducts nationally and internationally significant research into low-carbon energy production, environmental and social footprints of consumption, future environmental and resource scenarios, and the impacts on production and consumption systems of potential future disasters.

Keynote Speaker: Zinc Batteries for Sustainable Energy Storage

Dr. Zengxia Pei is a Lecturer and Horizon Fellow at the University of Sydney (USYD). He received his PhD in 2017 from City University of Hong Kong. He joined USYD in 2018 as a Vice-Chancellor's Research Fellow, and later he secured the ARC DECRA Fellowship in 2019. Dr. Pei works on nanomaterials for sustainable energy storage and conversion, with special interests in aqueous batteries, polymer electrolytes, as well as electrocatalysis. He has been consecutively recognized as a Global Highly Cited Researcher (Top 1%) in 2020-2023, and was named the Australian Research Top Rising Star (1 out of 5 in Chemical/Material Science) from 2019 to 2021. Dr. Pei was also awarded the USYD Vice-Chancellor's Award for Excellent Early Career Researcher in 2023.

Keynote Speaker: Value-Added Upcycling of Waste Solar Panels

Dr. Rasoul Khayyam Nekouei, graduated from UNSW in 2020 and was appointed as a Research Associate, where he focused on the valorisation of waste materials for the development of advanced and functional materials used in energy storage applications and wastewater treatment. In 2024, he was promoted to Lecturer at UNSW, expanding his research to include the development of innovative recycling methods for waste solar panels. His work aims to reduce the carbon footprint of waste disposal and contribute to sustainable materials processing. Rasoul's research interests lie at the intersection of waste management, materials science, and clean energy, with a particular focus on transforming e-waste into value-added products for energy storage and other high-tech applications.

Keynote Speaker: Biopolymer Nanocomposites for Wearable Electronics

Dr. Shuying Wu is currently a Senior Lecturer at the School of Aerospace, Mechanical and Mechatronic Engineering (AMME), The University of Sydney. Before joining AMME in September 2023, she was a Senior Lecturer at School of Engineering, Macquarie University since 2018 (ARC DECRA Fellow Oct 2018-Oct 2020), ARC DECRA Fellow at School of Mechanical and Manufacturing Engineering, UNSW (2017-2018), Research Fellow at School of Engineering, RMIT University (2014-2017) and Deakin University (2013-2014).

Net Zero Next Gen Assembly Program Committee

- **Dr Emma Lovell, UNSW Sydney (Co-Chairs)**
- **Dr Jingjing You, U Sydney (Co-Chairs)**
- **Dr Shuying Wu, U Sydney**
- **Dr Azrah Samsudeen, UNSW**
- **Dr Mandalena Hermawan**

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No	Title	Presenter
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2	Probing Plasma Methanation by Tuning Varying Bimetallic Properties of Al_2O_3 Supported Ni and Fe Catalysts	Mr Ahmad Zhafran Md Azmi (UNSW)
3	Carbon Footprint of Battery Energy Storage Under Performance Uncertainty	Dr Aisha Faruqi (USydney)
4	Hydrogen-enhanced carrier collection enables high bandgap Cdfree Cu_2ZnSnS_4 solar cells with 11.4% certified efficiency	Mr Ao Wang (USydney)
5	Decarbonising the production of ammonia	Dr Christopher Barnett (USydney)
6	Coupling Light and Heat: Synergistic Effects to Improve Catalyst Performance and Stability for Decarbonization Applications	Ms Elise Elkington (UNSW)
7	Techno-economic Analysis for Solar-Powered Electrochemical Reforming of Plastic Waste into Clean Hydrogen and Value-added Chemicals	Mrs Gavesha Gunasekara (UNSW)
8	Shining a light on methane dry reforming – exploring the impact of visible light on carbon formation	Mr George O'Connell (UNSW)
9	Engineering Geometrical Sites of Spinel Co_3O_4 by Regulating Ru Atom Doping for Highly Efficient and Stable Acidic Water Oxidation	Ms Huihui Li (UNSW)
10	Atomic-Level Engineering of Low-Cost Catalysts with Plasma-Enhanced Atomic Layer Deposition and Density Functional Theory	Dr Ina Oestroem (UNSW)
11	Hot Wheels – Hydrothermal upgrading of tyres to oil	Mr Jack Steel (USydney)
12	Advancing Gold Hydrogen Production: Integrating Micro-CT and Deep Learning for Mineral Phase Analysis	Mr Jiejie Li (UNSW)
13	Illuminating Metal-Support Chemistry: Tuning Oxygen Vacancies in Model Ni/CeO_2(100) Catalysts for Enhanced Photothermal Ammonia Decomposition	Mr Karan Menon (UNSW)
14	Revealing the role of vanadium-doped Ni_2P for enhanced urea oxidation	Ms Alvand Mahrouz (UNSW)
15	Improved graphene oxide reduction using bimetallic core-shell Ag-Pt nanoparticles	Mrs Mani Mani (UNSW)
16	Impact of geothermal heat losses on the performance of green hydrogen production	Mrs Maryam Hamlehdar (Univ of Melbourne)
17	Coupling Life Cycle and Process Engineering: A case study for Proton Exchange Membrane Electrolysis in New South Wales	Mr Michael Lejeune (UNSW)
18	A novel technology of co-injecting hydrogen and biomass in blast furnaces for a sustainable carbon-neutral ironmaking	Mr Ming Jiang Gan (UNSW)
19	Are electric flights ready for take-off?	Dr Mirjam Wiedemann(UNSW)

20	Social License, Policy and Paths to Large-scale Green Hydrogen Deployment: A Systematic Literature Review of Renewable Energy Expansion in Australia (2001-2024)	Mr Nehemia Gurusinga (Curtin Univ)
21	Enhanced Hydrogen Evolution Reaction in Alkaline Media via Ruthenium-Chromium Atomic Pairs Modified Ruthenium Nanoparticles	Ms Parisa Eskandari (UNSW)
22	Using Landscape Evolution Models to predict the Hunter (NSW) margin stratigraphy and hydrogen storage potential	Mr Rafael Cherene (USydney)
23	Hydrogen Fuel Cells as a Sustainable Replacement for Diesel Generators in Emergency Backup Power Systems for Australia's Critical Infrastructure	Mr Raveen De Silva (UTS)
24	Photo-Driven Reforming of Organic Waste to Hydrogen and Value-Added Chemicals	Mr Rehan Gunawan (UNSW)
25	High-throughput ammonia production from nitrate using liquid metal synthesised bismuth nano-catalyst	Miss Sahar Nazari (UNSW)
26	Electrocatalytic Approach for Net-Zero Sustainable Aviation Fuels	Ms Sumera Arshad (UNSW)
27	A hybrid plasma-electrochemical technology for green fertilizer production from nitrogen and carbon dioxide	Ms Trinh Dang Tran Bao (UNSW)
28	Unlocking the potential of electrochemical carbon extraction from seawater	Mr Wei Zhang (USydney)
29	Surface Reconstruction of CoAl Hydroxide Electrodes for Accelerated Oxygen Evolution Reaction	Ms Yanan Li (UNSW)
30	Co-Designing Policy for a Sustainable NSW Construction Industry	Mr Alan Murray (UTS)

Are electric flights ready for take-off?

Wiedemann, Mirjam; Konstantinou, Georgios, V, Anilan, Gao, Chenglong*

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Innovations for electric travel such as electric cars and electric aircrafts are well underway for road and air travel. However, the increased need for electricity and extra demands on the grid in the airport precinct and wider council areas are not well understood.

Most regional airports are owned and run by Council. Councils are facing the challenge to enable net zero transport on the road and in the air. With expected scaling-up of electric vehicles and electric flying to replace regional flights soon, there is an urgent need to understand energy infrastructure needs for airports. Furthermore, it is unclear whether electric or hydrogen will be the dominant solution for road and air travel in a decarbonised future.

This project explored different uptake scenarios of new propulsion systems for aircrafts including an all-electric and an all-hydrogen scenario. Using two regional NSW airports as case studies, it was found that the demand on the grid could be up to 1000 times higher than today. The researchers called for urgent consideration how those challenges could be managed and the cost burden for airports mitigated. The study also highlighted the complexity in airport precincts and challenges around load dispersion due to the nature of the air transport business. Future research could test findings on a wider sample taking different sizes and geographies of airports into account.

Enhanced Hydrogen Evolution Reaction in Alkaline Media via Ruthenium-Chromium Atomic Pairs Modified Ruthenium Nanoparticles

Parisa Eskandari[a], Shujie Zhou[a]*, Jodie Yuwono[a], Denny Gunawan[a], Zhipeng Ma[a], Jian Pan[a], Rose Amal[a], Xunyu Lu[a]*
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Abstract

Electrocatalytic water splitting powered by renewable energy sources is a highly efficient and sustainable method for producing green hydrogen, addressing challenges related to energy distribution while minimizing carbon emissions and fossil fuel reliance. Alkaline water electrolysis has gained significant interest due to its enhanced catalyst stability, practical feasibility, and cost-effectiveness compared to acidic processes[1, 2]. However, the alkaline hydrogen evolution reaction (HER) faces slow kinetics and low activity, primarily due to additional water adsorption and dissociation steps, which hinder affordable and scalable hydrogen production[3]. Therefore, developing efficient electrocatalysts with improved water adsorption and dissociation kinetics is essential for maximizing catalytic activity.

In this study, we present a novel strategy to develop cost-effective and highly active Ru-based electrocatalysts that enhance water adsorption and dissociation kinetics for alkaline HER. This approach modifies the electronic structure of ruthenium nanoparticles (Ru_{NPs}) by incorporating ruthenium single atoms (Ru_{SAs}) and Ru and Cr atomic pairs ($RuCr_{APs}$) onto a nitrogen-doped carbon (N-C) support through optimized electronic metal-support interactions (EMSI). The resulting catalyst, Ru_{NPs}-$RuCr_{APs}$-N-C, exhibits outstanding performance, achieving a mass activity of 11.33 $A \cdot mg^{-1}$ at an overpotential of 100 mV and a turnover frequency (TOF) of 13.15 s^{-1}, six times higher than commercial Pt/C (2.07 s^{-1}). Furthermore, this catalyst operates at a lower overpotential of 31 mV at a current density of 10 $mA \cdot cm^{-2}$, surpassing both Pt/C and Ru_{NPs}-Ru_{SAs}-N-C. Experimental results and DFT calculations reveal that the electronically modified Ru NPs serve as the main active sites for enhanced HER performance, with Ru-Cr interactions playing a crucial role in optimizing EMSI effects, facilitating water adsorption, and modulating hydrogen desorption. This work provides valuable insights for the design of atomic species-modified electrocatalysts for alkaline HER and other applications.

References

[1] Z. Y. Yu, Y. Duan, X. Y. Feng, X. Yu, M. R. Gao, and S. H. Yu, "Clean and affordable hydrogen fuel from alkaline water splitting: past, recent progress, and future prospects," *Advanced Materials,* vol. 33, no. 31, p. 2007100, 2021.

[2] H. Hong *et al.*, "Surface-functionalized three-dimensional MXene supports to boost the hydrogen evolution activity of Pt catalysts in alkaline media," *Journal of Materials Chemistry A,* vol. 11, no. 10, pp. 5328-5336, 2023.

[3] F. Liu *et al.*, "Rational design of better hydrogen evolution electrocatalysts for water splitting: a review," *Advanced Science,* vol. 9, no. 18, p. 2200307, 2022.

Surface Reconstruction of CoAl Hydroxide Electrodes for Accelerated Oxygen Evolution Reaction

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Water electrolysis powered by renewable energy is recognized as a sustainable approach for green hydrogen production. Rational design of efficient and low-cost electrocatalysts especially for the sluggish oxygen evolution reaction (OER) remains a significant challenge. Here, we report a two-step surface reconstruction strategy, alkaline etching and anodic activation on CoAl hydroxide electrodes that remarkably enhance OER performance. A low overpotential of 269 mV at 10 mA cm^{-2} is achieved in 1.0 M KOH electrolyte, along with a notably reduced Tafel slope of 37 mV dec^{-1}, a 25-fold enhanced catalyst intrinsic activity at an overpotential of 300 mV, and an excellent stability without noticeable degradation over 50 hours operation. The dynamic surface reconstruction of CoAl hydroxide catalyst is evidenced by physical characterization in the process of alkaline etching and anodic activation, and the defective structure and the modulated electronic distribution on the catalyst surface is demonstrated to facilitate electron transfer and OER kinetics. Our work presents a feasible surface reconstruction approach for designing high-efficiency electrodes in alkaline water electrolysis.

Photo-Driven Reforming of Organic Waste to Hydrogen and Value-Added Chemicals

Rehan Gunawan, Denny Gunawan, Jason Scott, Rose Amal

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Environmental pollution from industrial and household waste remains a pressing challenge, largely due to outdated waste management practices that contribute to significant ecological harm. In response, this study investigates the potential of integrating photocatalysis into traditional waste management to reform organic waste, converting it into hydrogen and value-added chemicals. Photoreforming uses photocatalysts to activate and break down organic compounds in waste, providing an alternative pathway for producing clean energy and valuable resources before the waste is fully discarded.

The primary objective is to assess whether this approach can offer an economically viable and environmentally sustainable solution to current waste management issues. By utilizing the chemical potential of organic waste through photocatalysis, the process not only reduces the harmful effects associated with conventional disposal methods, such as landfilling and incineration, but also promotes a circular economy by generating hydrogen and other useful by-products.

Preliminary findings indicate that integrating photocatalysts into existing waste treatment infrastructure could offer significant environmental benefits, including the potential for negative greenhouse gas emissions when coupled with fully renewable energy sources (-1.4 kg CO_{2eq}/kg organic waste), such as solar power. Moreover, early economic assessments suggest that, while this innovative approach may involve slightly higher upfront costs compared to traditional methods, it remains competitive, with an estimated treatment cost of 0.1–0.2 USD per kilogram of organic waste. This approach delivers substantial long-term value through environmental sustainability and resource recovery benefits.

This study aims to further explore the scalability, efficiency, and economic feasibility of this approach, offering a potentially transformative solution for addressing global waste management challenges while contributing to renewable energy production.

Probing Plasma Methanation by Tuning Varying Bimetallic Properties of Al_2O_3 Supported Ni and Fe Catalysts

Ahmad Md Azmi[1], *Jason Scott**[1], *Emma Lovell*[1], *Yunxia Yang*[2], *Anthony B. Murphy*[3]

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Research surrounding CO_2 mitigation through carbon capture, storage and utilization is being increasingly explored to mitigate anthropogenic climate change. Particularly CO_2 methanation, to reduce CO_2 emissions while generating added value products (CO_2 and H_2 into CH_4). Conventional CO_2 methanation necessitates high temperatures to overcome energy activation, which imposes thermodynamic limitations and constrain practical industrial applications. Thus, the use of non-thermal plasma (NTP) has garnered interest in catalytic research due to the generation of high energy species while maintaining low bulk temperatures. Despite plasma methanation successfully demonstrating conversions of CO_2 into CH_4, its reaction performances still fall behind conventional thermal reactions. Given the noticeable gap in research around the catalytic properties driving the reaction, this work examines bimetallic Ni and Fe supported by Al_2O_3 under thermal and plasma methanation conditions to elucidate catalyst characteristics critical for plasma methanation. To vary the bimetallic properties, catalysts with Ni and differing amounts of Fe were produced via wet impregnation (WI) and deposition precipitation (DP). For both methods, catalysts with small amounts of Fe demonstrated peak performances under thermal conditions in terms of CO_2 conversion and CH_4 selectivity, attributed to the Ni and Fe functioning independently, yet synergistically. Under plasma conditions, by varying metal-metal interactions, the plasma performance was tuned. The DP samples produced Ni species that were stabilized by the alumina, allowing for improved plasma reaction performances through bimetallic synergies as observed in thermal methanation. Conversely, the WI plasma performance peaked with large amounts of Fe, where the oxidation states of the Ni were significantly affected by the addition of Fe. Thus, the improved reaction performance under plasma was attributed to the variations in electron distribution. This study provides a greater understanding of catalyst design for plasma-enhanced CO_2 methanation, providing a step forward to making methanation a more sustainable means of CO_2 utilization.

Enhanced Stability of Cu_2O Photocathodes via Carbon-Based Nanostructures Protection Strategy for Water Splitting Applications

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Cuprous oxide stands out as a promising material for photocathodes due to its direct bandgap of 2.1 eV, making it suitable candidate for photoelectrochemical water splitting. However, its susceptibility to photocorrosion due to their redox potential that lies within the bandgap makes it viable for both reduction and oxidation reactions to occur, which limit its efficiency and lifetime. To address the issue, this study presents a novel, metal and metal oxide-free approach to enhance the stability and efficiency of cuprous oxide (Cu_2O) photocathodes for photoelectrochemical (PEC) water splitting. Cu_2O photocathodes were fabricated on porous Cu foam via electrochemical anodization and protected by a carbon-based coating of reduced graphene oxide (rGO) and acetylenic carbon-rich nanostructure. The material exhibited remarkable photoelectrocatalytic activity, yielding a saturated cathodic photocurrent of 1.5 mA at 0 V vs. RHE with 80% stability after 1 hour. The insights into the synergistic effects of rGO and acetylenic carbon-rich materials in stabilizing Cu_2O photocathodes are also demonstrated, proving the potential candidate for efficient, durable PEC water splitting applications.

A novel technology of co-injecting hydrogen and biomass in blast furnaces for a sustainable carbon-neutral ironmaking

*Ming Jiang Gan, Yiran Liu and Yansong Shen**

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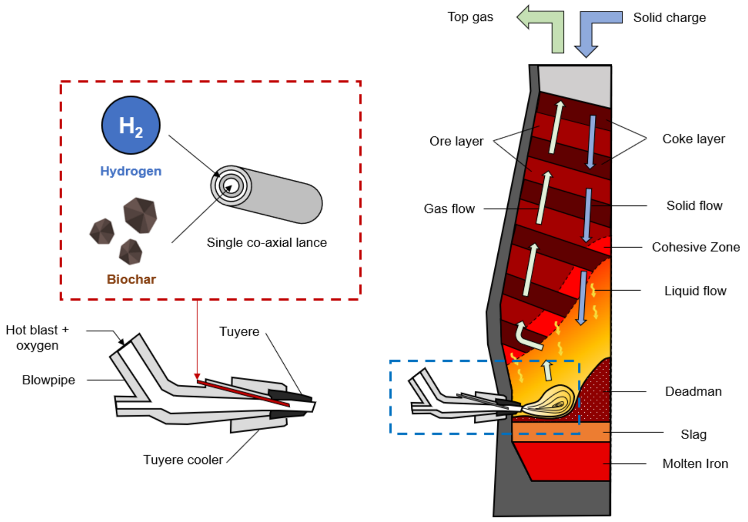
We propose a sustainable and feasible carbon-neutral ironmaking technology – the co-injection of hydrogen and biomass in blast furnaces.[1,2] To understand the fundamentals of internal combustion behaviour related to the co-injection of hydrogen and charcoal, a three-dimensional computational fluid dynamics (CFD) model is developed by describing the multiphase reacting flow under the simulated BF conditions. Particularly, the present model features a new treatment of volatile matter and an improved sub-model for hydrogen combustion. The model is validated by two cases of charcoal injection and co-injection of hydrogen and coal. The typical in-furnace phenomena as well as the interaction between the hydrogen and charcoal are analysed comprehensively. The results indicate that the proper injection of hydrogen through the annulus of the charcoal lance is beneficial as high local gas temperatures (1500 K to 1800 K) from hydrogen combustion provided a charcoal burnout enhancement of 6% during the charcoal devolatilisation process. However, char reactions are hindered due to oxygen competition with hydrogen combustion, hence resulting in a slightly reduced final burnout. This study provides a quantitative tool for the study of this frontier technology, which may serve as a reference to strive toward the net-carbon initiative.



Schematic diagram of the tuyere injection process and the conveyance method through a single co-axial lance

Schematic view of the co-injection of hydrogen and biomass in a blast furnace

Figure 1 *Schematic diagram of the novel technology of the CoHB process in a BF*

References

1 M. J. Gan, Y. Liu and Y. Shen, *Fuel*, 2023, **350**, 128745.
2 International (PCT) Patent Application No. PCT/AU2023/051167, 2023.

Social License, Policy and Paths to Large-scale Green Hydrogen Deployment: A Systematic Literature Review of Renewable Energy Expansion in Australia (2001-2024)

Nehemia Gurusinga, Prof. Peta Ashworth, A/Prof. Katherine Witt**
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Abstract

This systematic review studied the relationships between Social License to Operate (SLO), government policies, and the expansion of renewable energy (RE) during 2001-2024 in Australia. By synthesising over twenty years of evidence, we identified the critical aspects influencing social acceptance and successful deployment of RE projects, which currently contribute to nearly 40 per cent of electricity generation from renewables. The findings revealed that policies have played an important role in enabling RE expansion but were restricted by fossil fuel supporters, inconsistent strategies, and insufficient community engagement. The review emphasises the importance of social acceptance and meaningful stakeholder involvement if we are to succeed in the deployment of gigawatt-scale RE projects.

Besides monetary benefits, future policies will need to embrace local decision-making, community benefits, and democratic principles (community engagement, bottom-up approach, and local-ownership) particularly if there is an end goal to develop green hydrogen which will require X times more installed RE capacity. The review found that knowledge gaps exist in the lack of comparative regional studies, the importance of justice principles, and longitudinal investigations associated with the dynamics of social acceptance. By doing so, it will help Australia to build social pathways that endorse large-scale green hydrogen deployment.

Keywords: Systematic Literature Review, Social License to Operate (SLO), Green Hydrogen, Australia, Renewable Energy, Policy

Using Landscape Evolution Models to predict the Hunter (NSW) margin stratigraphy and hydrogen storage potential

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The Australian federal government recently declared an offshore wind power generation zone offshore the New South Wales Hunter coast, in response to the increasing interest of state and federal government goals of transforming the energy mix, reducing our dependence on coal, and increasing the share of renewable energy. In this context, green hydrogen plays a crucial role. However, given the large volumes of hydrogen needed for power generation and potential future export, above-ground storage remains a challenge. Instead, geological storage of hydrogen is an approach needed to address the volume and safety requirements.

Using an open-source landscape evolution model (Badlands), this study aims to predict the Hunter margin stratigraphy deposited during the Cenozoic, analysing the sedimentation patterns and sea level variations during greenhouse and icehouse climate periods. Sediment thicknesses compiled from previous seismic and drillhole data in the Hunter region were used to adjust the model's output, ensuring the accurate representation of Cenozoic shelf sediment wedge. In addition, a reference profile of the east coast of Australia was generated to refine input parameters and better define the model's initial condition.

Our hypothesis is that these rapid sea level fluctuations directly influenced sediment deposition patterns, forming successive sequences that could potentially serve as seals for the safe storage of hydrogen, given the high mobility of the gas. In contrast, stable sea levels with more gradual changes are expected to generate sedimentation patterns that present potential to store the hydrogen due to their appropriate porosity and permeability.

Understanding these patterns is crucial for optimising target selection and ensuring that the proposed storage sites for hydrogen are both efficient and secure. This research contributes to the NSW and Australia goal of net-zero emissions by 2050 and provides valuable insights for stratigraphic forward modelling and hydrogen storage analyses in other passive margin regions.

Coupling Light and Heat: Synergistic Effects to Improve Catalyst Performance and Stability for Decarbonization Applications

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Ammonia shows promise as a medium for hydrogen storage and transportation. Challenges arise in recovering hydrogen at the point of use [1]. This is mainly due to elevated reaction temperatures and dependence on costly noble metal catalysts to drive the ammonia decomposition reaction (ADR). An emerging field of work in catalysis involves the incorporation of sunlight into thermal catalytic systems as a means of lowering the reaction temperature to offset energy requirements, known as thermo-photo catalysis [2,3]. In this study, a series of bimetallic xNi-(10-x)Co/CeO_2 (x = 0, 2.5, 5, 7.5, 10) catalysts at a constant 10 wt.% metal loading were synthesized. The ADR was explored under both thermal (T) and thermo-photo (PT) conditions.

All catalysts exhibited a performance increase of at least 15% under photothermal conditions at temperatures up to 550°C. The 5Ni-5Co catalyst demonstrated the highest performance under all conditions, achieving 45.1% conversion at 550°C under PT conditions. The next-best performing catalyst (10Ni) only achieved 38.8% conversion at the same temperature.

Investigation via H_2-TPR, XEDS mapping, and XRD revealed a unique synergy between the Ni and Co. This synergy enhanced metal dispersion over the support and reduced the average particle size, thereby increasing the number of active sites for the reaction. Cyclic light-dark testing and XPS on spent catalysts suggested that light played a dual role in enhancing the reaction: localized heating and a decreased energy barrier for the rate-determining step of nitrogen desorption.

This work underscores the potential of a thermo-photo system to enhance the performance of catalysts for the ADR over transition metal catalysts for the first time. Importantly, these findings open new avenues for advancing sustainable and efficient hydrogen recovery from ammonia under environmentally favorable conditions.

Impact of geothermal heat losses on the performance of green hydrogen production

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To accurately evaluate the performance of a geothermal-based hydrogen production system, it is crucial to model how variations in geothermal temperature over time impact the system's performance throughout the reservoir's lifespan. This study undertakes a 30-year techno-economic assessment of an Organic Rankine Cycle (ORC)-based hydrogen production system using geothermal energy at a site in Australia. A hybrid numerical model that combines simulations of the underground geothermal reservoir with the above-ground hydrogen production components, is employed. The geothermal system is accurately simulated using a full geometry 3D finite element (FE) model to assess heat loss in wells and its impact on a geothermal-based hydrogen production system's performance throughout its operational lifespan. The findings reveal that there is a temperature gap between the bottom and top of the production well due to heat losses, which can significantly impact the hydrogen production cost and rate. For the case analysed herein, during the initial operational phase (first 5 years), a 7.3 °C temperature gap is observed between the bottom and top of the production well, leading to a variation of 19.33% in hydrogen production rate and of 12% in costs. However, the well temperature variation gradually decreases to only 1.4 °C over the last 10 years, resulting in a 4% decrease in hydrogen production rate and a 9% increase in the hydrogen cost with respect to the case where the well temperature variation is not accounted for. Overall, this paper shows that the inclusion of all ground layers is essential in the integrated numerical modelling of hydrogen production systems, as one must consider the thermal interaction between wellbores and the surrounding impervious ground layers above the aquifer geothermal reservoir.

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

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Mitigating climate change requires decarbonising heavy-emitting sectors and industries to reach net-zero emissions by 2050[1]. Hydrogen is a key lever in decarbonisation efforts as an energy vector and chemical feedstock, provided it is produced using renewable energy[1]. The New South Wales (NSW) government has recently introduced large renewable energy zones (REZs)[2] where low-emission hydrogen could be produced in large scales. Yet, no comprehensive assessment of the global warming potential (GWP) in these REZs has been conducted. This work uses a novel approach coupling life cycle and process engineering (LCE and PE) to evaluate the GWP and abatement of electrolytic hydrogen production with a proton exchange membrane electrolysis plant[3]. This analysis is then extended using geospatial analysis to evaluate the impact of REZs across NSW. Results show that implementing LCE principles in PE could abate half of the cumulated GWP by 2050. GWP results for the selected REZs show an average of ~1.45kgCO_2e/kgH_2. Ultimately, this preliminary assessment informs relevant stakeholders on the potential environmental impact of hydrogen produced from REZs. Future work should extend the present study by evaluating the potential water footprint and other impact categories for green hydrogen produced from these REZs.

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Decarbonising the production of Ammonia
A 3D printed test reactor

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Ammonia is essential to humanity. Over half of the people currently alive *could not exist* if nitrogen were not fixed into ammonia in the Haber Bosch process. Each year, over 150 million tonnes of ammonia are produced through artificial nitrogen fixation,[1] responsible for 1.2% of global carbon dioxide emissions. The production of this vital resource needs to be decarbonised, with multiple solutions working together.

Efficient aqueous electrochemical fixation, at atmospheric temperature and pressure, would decarbonise the process, and be a key step towards being commercially competitive with the Haber-Bosch process. The field of electrochemical fixation of dinitrogen to ammonia is fraught with false positives.[3] An issue with aqueous electrochemical processes is that dinitrogen is sparingly soluble in water. To solve these problems, we looked to water in nitrogen, using a gas diffusion electrode setup, with careful controls to avoid false positives.

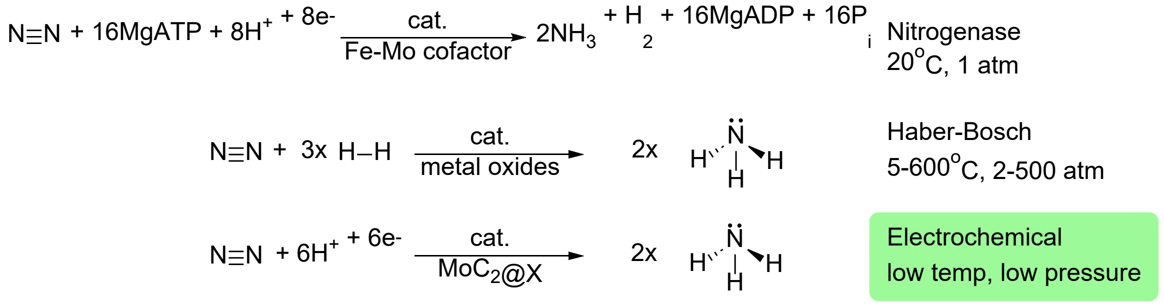

Figure 1: Comparison of the two well established methods of nitrogen fixation, that of nature – nitrogenase, and that of humanity – the Haber-Bosch process.[2] Electrochemical fixation, the target

This presentation describes our recent success in testing the catalysts in gas-phase electrochemistry. To enable this research, a modular, cheap, and easily 3D printed device was designed and tested, allowing for parallel testing of multiple catalysts, and optimisation of process parameters. Both preliminary results and the reactor design will be presented.

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Improved graphene oxide reduction using bimetallic core-shell Ag-Pt nanoparticles

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Surface plasmon resonance (SPR) presents compelling prospects for amplifying photocatalyst efficiency through the generation of "hot electrons" during surface plasmon decay. This holds the potential to elevate conversion yields in solar energy technologies[1]. However, there is a hitch in this process that the hot electrons tend to recombine with the holes. Extensive research is underway to investigate bimetallic photocatalyst nanoparticles, aiming to boost the mobility of these electrons towards active sites[2]. In our research, we endeavoured to provide evidence for this concept by reducing Graphene Oxide with visible and IR light. Under light exposure, the coupling of GO with Ag-Pt nanoparticles resulted in the highest observed conversion, as confirmed by UV-vis absorbance data, FTIR analysis, and conductivity measurements. This can be ascribed to the enhanced transfer of hot electrons from the plasmonic (Ag) nanoparticles to GO facilitated by the Pt islands.

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Electrocatalytic Approach for Net-Zero Sustainable Aviation Fuels

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Demand for energy and natural resources (fossil fuels) is primarily driven by industrialization, population growth, and globalization. Developing countries require inexpensive, reliable, and environmentally friendly energy systems to support economic and social development. Petroleum is the transportation industry's primary source of diesel and gasoline. The aviation sector is a crucial component of the transportation industry. Energy consumption and emission of greenhouse gases from transportation is predicted to rise to 80% by 2030. To combat the environmental impact of traditional fuel used in aviation, multiple organizations, including the IATA (International Air Transportation Authority), are investing resources in promoting the production and utilization of sustainable aviation fuel, which emits 80% less pollutants throughout its entire lifespan in comparison to conventional jet fuel (kerosene). At the maximum integrating ratio, SAF can potentially replace traditional aviation fuel. The aviation industry must reduce worldwide emissions by around 65% and include carbon offsetting to attain net-zero CO_2 emissions by 2050.

There are many ways to synthesize SAF, but all current methods, such as the Alcohol-to-Jet pathway (ATJ) and hydrogenation of oils and fats (HEFA), are limited due to the high capital cost that translates into a relatively high-cost biofuel. Truly renewable “green field” biofuel from conventional methods would also rely on a source of green hydrogen from water splitting, which currently contributes to biofuel cost barriers. The Kolbe process is an electrochemical method that uses low-carbon feedstock to transform carboxylic acids into high-quality hydrocarbons, suitable for "drop-in replacement" biofuels, specifically from waste fats and oils like waste cooking oil WCO and tallow. This project aims to use a Kolbe technique with flat platinum catalysts to produce hydrocarbons and characterize products via GC-MS and NMR. Initial estimates of yields obtained from Kolbe electrosynthesis are good, with above 65% of the products being dimerized long-chain alkane hydrocarbons and a total yield of oxygen-free biofuel molecules above 90% overall. The research will revolutionize the aviation fuel industry by accommodating new pathways to create a sustainable SAF and reduce carbon emissions. Furthermore, the study will contribute to meeting global emission targets for the aviation sector by reducing fossil fuel dependency, to enable widespread low-carbon air travel.

Atomic-Level Engineering of Low-Cost Catalysts with Plasma-Enhanced Atomic Layer Deposition and Density Functional Theory

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Hydrogen production through water splitting is hindered by the anodic oxygen evolution reaction (OER), which has a complex, sluggish mechanism leading to a high overpotential. Nickel oxide-based catalysts (NiO_x) are a highly active, cheaper alternative to the precious metal catalysts of IrO_2 and RuO_2. Plasma-enhanced atomic layer deposition (PE-ALD) is a versatile tool for optimising thin films catalysts to the atomic level and enhance OER activity. This work combines PE-ALD and density functional theory (DFT) to design and develop optimised different types of catalysts for OER. First, we test and explain the role Zn^{2+}, Al^{3+} and Sn^{4+} dopants in improving NiOx OER activity with DFT. The best catalysts film $SnNiO_x$ is then further improved by deposition of atomically dispersed catalysts (ADCs) of Fe_1 and Co_1, prepared in different plasma environments (O_2 and H_2). Our results show that atomically dispersed Co_1 and Fe_1 produced via H_2 plasma, in contrast to an O_2 plasma, further improved the OER activity of thin films of $SnNiO_x$. The best OER catalyst, $Fe_1Co_1/SnNiO_x$ with 254 mV of overpotential at 10 mA/cm^2 on FTO and 1M KOH, can be compared with 320 mV for Ru catalyst on glassy carbon (GC) in 1M NaOH, with remarkable stability and durability after prolonged test. Tafel analysis indicated that all catalysts had optimal OER mechanism, and the electrochemical impedance showed that $Fe_1Co_1/SnNiO_x$ had lower charge-transfer resistance (R_{ct}). All-electron hybrid DFT (PEB0/pob-TZVP) provided insights about the electronic properties of the catalysts. X-ray diffraction, X-ray photoelectron spectroscopy, X-ray absorption characterised the atomic structure, active sites oxidation state and coordination environment. The morphology and conformality was analysed with atomic force microscopy (AFM), transmission electron microscopy (TEM), and scanning electron microscopy (SEM). Our study highlights PE-ALD and DFT as a promising technologies for optimising low-cost catalysts with high atom economy and atomic level precision.

Engineering Geometrical Sites of Spinel Co_3O_4 by Regulating Ru Atom Doping for Highly Efficient and Stable Acidic Water Oxidation

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Proton exchange membrane water electrolyzer (PEMWE) is an attracting leading technology for producing H_2 at commercial-scale[1-2]. However, its commercialization is largely hindered by the limited stability of oxygen evolution reaction (OER) under harsh conditions. While Ru-based materials have shown potential in this area, their scarcity and high price contribute to elevated operational expanses. Utilizing inexpensive but stable transitional metal oxides as supports is an effective strategy to reduce Ru content and enhance both OER catalytic activity and stability[3-4]. In this study, the single atom Ru doped Co_3O_4 was synthesized by a combination of electrodeposition, cation exchange, and post-thermal annealing treatments. Our synthesis strategy effectively achieved the substitution of Co at octahedral sites with Ru atoms to the greatest extent. The bridging oxygen unit "Ru_{oct}-O-Co_{oc}t" allows the surrounding electron-enriched tetrahedral Co atoms to supply electrons to Ru_{oct} and Co_{oct} sites, thereby suppressing the dissolution. The resulting single atom Ru-doped Co_3O_4 exhibited an overpotential of 187 mV (after 85% iR compensation) in 0.5 M H_2SO_4, as well as superior stability performance (over 109 days chronopotrntiometry tests) at 10 mA cm^{-2}, with an ultralow potential decay rate of 0.011 mV h^{-1}. This performance surpassed most of the state-of-art noble metal-doped cobalt oxide electrocatalysts. Even during prolonged operation, some of Ru species were inevitably oxidized to RuO_2, forming the heterostructure RuO_2/Ru-doped Co_3O_4. The Ru-doped Co_3O_4 functions as an electron reservoir, supplying electrons to the RuO_2 and preventing overoxidation and dissolution. Our work provides a systematic investigation into the "structure-stability" mechanism of the acidic OER process, contributing to a deeper understanding the design for stable and efficient water oxidation.

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Hydrogen Fuel Cells as a Sustainable Replacement for Diesel Generators in Emergency Backup Power Systems for Australia's Critical Infrastructure

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Transitioning from Diesel Generators (DG) to Hydrogen Fuel Cells (HFC) in Australian emergency backup power systems signify an essential move towards sustainability in critical infrastructure. DGs account for approximately 15% of emergency power solutions globally [1,2], contributing around 10% of total greenhouse gas emissions from non-renewable sources [3,4]. This reliance on DGs poses significant environmental risks, as it results in CO_2, NOx, and particulate matter emissions, which are major contributors to air pollution and climate change [4]. While HFCs involve higher upfront costs, typically 30% more than DGs, the cost disparity is expected to narrow in the coming years. By 2030, hydrogen production costs are projected to decrease to A\$2–A\$3/kg [5,6], making hydrogen economically competitive with diesel. Additionally, HFCs have operational advantages, such as reduced maintenance requirements and the elimination of fuel combustion, which can lower operational costs by up to 40% [7]. DGs, on the other hand, incur regular servicing and fuel expenses, which can comprise up to 20% of their total operational costs [7]. Environmentally, HFCs offer a clean alternative, emitting only water vapor, and their adoption could reduce greenhouse gas emissions from backup power systems by up to 90%. This transition aligns with Australia's commitment to achieving net-zero emissions by 2050 [8,9], and the government's \$2 billion Hydrogen Headstart program aims to accelerate the uptake of renewable hydrogen technologies [10]. HFCs provide rapid power delivery essential for critical infrastructure and are compatible with renewable energy sources, enhancing resilience. Utilizing a digital twin technology offers real-time monitoring and predictive maintenance capabilities, optimizing system performance and lifespan. HFCs can be recognized as a promising alternative to DGs, supporting Australia's shift towards a low-carbon economy and addressing the environmental limitations of traditional backup power solutions. As advancements continue, green hydrogen is expected to become an increasingly vital component of Australia's energy infrastructures, offering both economic and environmental benefits.

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Illuminating Metal-Support Chemistry: Tuning Oxygen Vacancies in Model $Ni/CeO_2(100)$ Catalysts for Enhanced Photothermal Ammonia Decomposition

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The hydrogen economy, relying on hydrogen as the primary energy source, faces hydrogen transport and storage challenges. Alternatively, ammonia can be a viable carrier for hydrogen, leveraging existing infrastructure. The critical challenge is developing an efficient catalyst for ammonia decomposition to produce hydrogen. For this, it is necessary to identify and target the rate-determining steps(RDS). RDS can be identified and targeted using model catalysts. These 'model' catalysts are simplified versions of real and more complex catalysts and are simple enough to be realised through experiments and computations. To understand the influence of the support's surface chemistry on the photothermal decomposition of ammonia, we synthesise a $Ni/Ce_{1-x}La_xO_2$-y(100) catalyst by incorporating La^{3+} into the CeO_2 lattice to tune oxygen vacancies. Our observations indicate that as the percentage of La^{3+} increases, the intrinsic oxygen vacancies in the support also increase, resulting in an enhanced ammonia decomposition under light and thermal conditions. We propose that intrinsic oxygen vacancies are essential in creating Lewis acid-base pairs that can promote the ammonia decomposition process.

Co-Designing Policy for a Sustainable NSW Construction Industry

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Decarbonising the construction industry is critical for New South Wales (NSW) government departments, meet their climate goals and reduce the sector's significant environmental impact. This article examines the political critical success factors (CSFs) necessary to drive the industry's transition towards low-carbon practices. Implementing circular economy policies in the construction industry requires a thorough and unified political strategy to establish the groundwork for a significant transition towards sustainability (Ancapi et al., 2022). This strategy must include a set of strong regulations that promote and require the implementation of sustainable practices. The approach should balance regulations with incentives to stimulate innovation, and importantly not constrict the market (Ghufran et al., 2022). These factors include strong government leadership, the implementation of stringent legislative frameworks, and the alignment of decarbonisation policies with global climate commitments. The role of financial incentives, such as carbon pricing and credits, is explored alongside the importance of stakeholder engagement and cross-agency coordination as identified in Figure 1. Furthermore, the article highlights the need for innovation-driven policies that support research and the digital integration of decarbonisation tools. By focusing on these political CSFs, NSW can accelerate the construction industry's shift toward a more sustainable future while overcoming regulatory, financial, and market challenges. This research is supported by the NSW Building Commission as part of the world first Construction Industry Doctorate Program and contributes to the growing body of knowledge on how political leadership can foster sustainable practices within one of the state's most carbon-intensive industries.

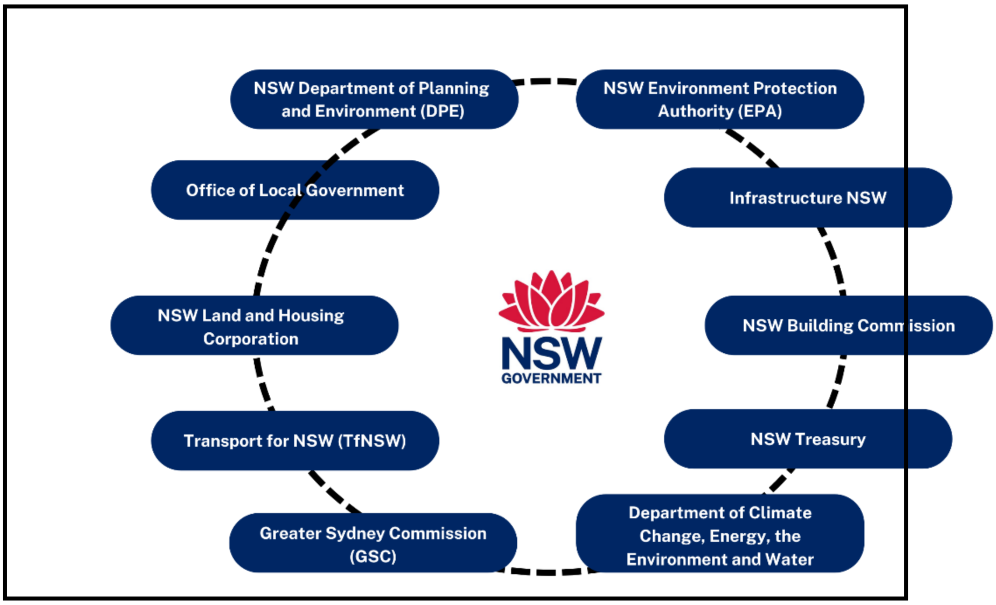

Figure 1: Major NSW Infrastructure Construction Sustainability Stakeholders (Author, 2024)

Hot Wheels – Hydrothermal upgrading of tyres to oil

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One of the big environmental challenges that must be solved this century is how to deal with the mounting quantities of plastic waste that are generated each year. Plastics do not break down in the environment, so this solution is going to require more advanced and efficient methods to recycle these polymers so that they may be reused in a closed loop economy.

One such technique is hydrothermal liquefaction, which uses supercritical water to break down polymers into smaller molecules that have the consistency of a crude oil. This oil can be processed using conventional petrochemical facilities into the same monomers that the plastics were synthesised from initially. This poster will focus on the hydrothermal recycling of used tyres. The oil generated from recycling these tyres will be characterised and some insights into the mechanism will be provided through the analysis of experiments with model compounds.

Figure 1: A visual representation on the 'hot wheels' of the future, generated by Microsoft Copilot.

Shining a light on methane dry reforming – exploring the impact of visible light on carbon formation

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The dry reforming of methane reaction (DRM) provides a unique method to valorise the two most significant greenhouse gas molecules (CO_2 and CH_4) by producing renewable fuels (Equation 1) [1]. While an effective strategy to tackle climate change, DRM is limited by high operation temperatures, poor reaction selectivity and susceptibility to deactivation by carbon deposition [2]. Inducing localised surface plasmon resonance (LSPR) by illuminating traditional thermocatalysts may provide a means to offset the energy requirements and promote a stable reaction pathway, where light facilitates the release of O atoms trapped in surface oxygen vacancies (SOVs), thereby oxidising CH_4 as it dehydrogenates [3,4]. While studies have demonstrated light's potential to prevent carbon accumulation, others suggest light promotes carbon deposition, indicating that light's influence on the DRM reaction is poorly understood [5,6]. The impact of visible light on the DRM carbon deposition was investigated by systematically incorporating CeO_2 into Co/Al_2O_3, thereby changing the support's SOV concentration and oxygen release capacity.

$$CH_4 + CO_2 \rightleftharpoons 2CO + 2H_2 \qquad (1)$$

This talk will present several novel perspectives on light's role in DRM stability. Incorporating CeO_2 was an effective strategy in preventing carbon formation under thermal conditions, achieving ~ 80% carbon reduction for $Co/5CeO_2\text{-}Al_2O_3$ ($T = 650$ °C). However, the extent of catalyst deactivation increased significantly for all catalysts upon illumination (up to 5.7x CO_2 conversion deactivation extent) as light accelerated CH_4 dehydrogenation, resulting in the formation of detrimental whisker carbon from its more active amorphous precursor (Figure 1). The work demonstrated for the first time that the rate of CH_4 dehydrogenation on the active metal must be balanced with the CH_x oxidation rate ($x = 0 – 3$) under light to achieve DRM stability improvements. By understanding light's role in the CH_x oxidation and dehydrogenation rates, a stable, light-receptive catalyst may be pursued.

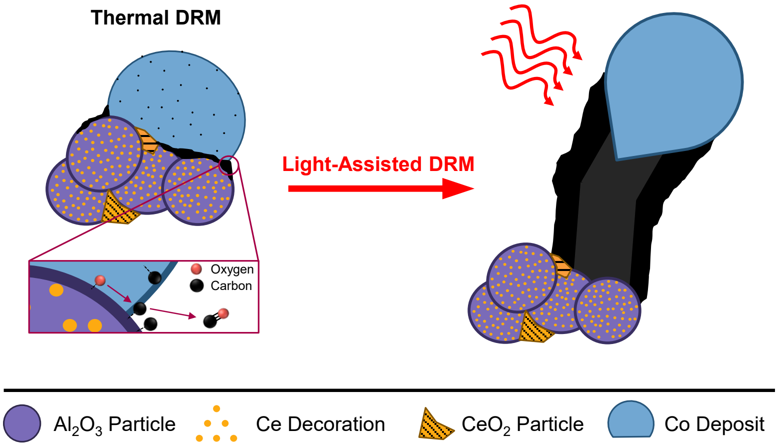

***Figure 2:** Under thermal conditions, the release of O trapped in SOVs oxidises surface carbon, preventing carbon accumulation. For light-assisted DRM, the rate of CH_x dehydrogenation is accelerated, unbalancing the CH_x oxidation rate ($x = 0 – 3$), resulting in deactivation by the light-facilitated formation of carbon whiskers.*

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Techno-economic Analysis for Solar-Powered Electrochemical Reforming of Plastic Waste into Clean Hydrogen and Value-added Chemicals

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Plastic waste generated worldwide is mainly mismanaged, incinerated or sent to landfills, while only a small portion is recovered and recycled[1]. However, mechanical recycling can deteriorate the thermal and mechanical properties of the virgin polymer due to continuous degradation while most existing thermochemical upcycling processes are energy-intensive. Electrocatalytic upcycling of plastic to commodity chemicals and H_2 is a sustainable alternative.

The poster will present novel results related to the preliminary techno-economic analysis (TEA) for electrocatalytic upcycling of polyethylene terephthalate (PET) plastic waste to produce clean H_2 and value-added chemicals: potassium diformate (KDF) and purified terephthalic acid (PTA). This TEA shows the feasibility of a small-scale waste reforming facility that treats PET waste generated in 3000 households (~300 kg of PET waste/day). Under the base case scenario, the results indicate a net present value (NPV) of ~AU$800,000- 1,300,000 for a project lifetime of 25 years with a payback period of ~6-7 years. The revenue generation of this process is through selling the products where H_2, KDF, and PTA contribute around 1.6%, 74.8%, and 23.6% of the total revenue, respectively. Further, an alternative scenario considering a solar PV-powered system with no battery storage shows lower cost compared to a grid-connected system, a solar PV-powered system with a 4-hour battery storage, and a solar PV-powered system with an 8-hour battery storage. Overall, the cost of PET waste reforming through electrocatalytic upcycling ranges from AU$0.01-0.23/kg of PET waste when considering 100% of the products sold. The estimated cost of electrochemical PET waste reforming is comparable to that of conventional plastic recycling processes (AU$ 0.1-2.74/kg of PET waste)[2], highlighting the competitive advantage of the PET waste electrolysis pathway.

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A hybrid plasma-electrochemical technology for green fertilizer production from nitrogen and carbon dioxide

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In Australia, agriculture is considered as one of the crucial sectors, in which fertilizer production, urea, is in a large demand. Currently, urea is conventionally produced via Haber- Bosch process under extreme conditions, raising high energy consumption and environmental concerns. In recent years, plasma technology has become one of the promising solutions to such non-equilibrium thermodynamic or energy-intensive reactions, which has been studied in waste recycling and gas conversion applications[1,2]. By combining plasma catalysis with electrochemical conversion, a hybrid technology is possible to study urea production.

To date, little of investigation has been examined the effects of co-fed nitrogen and carbon dioxide in plasma activation with electrocatalysis to produce C-N compounds, including urea, with a clear understanding of reaction mechanisms and quantification methods. Our work is currently working on these pain points by evaluating the functions of plasma activated species and understanding the catalytic role of Cu-loaded ZnO in the electro-reduction, driving the conversion to urea derivatives from nitrogen and carbon dioxide.

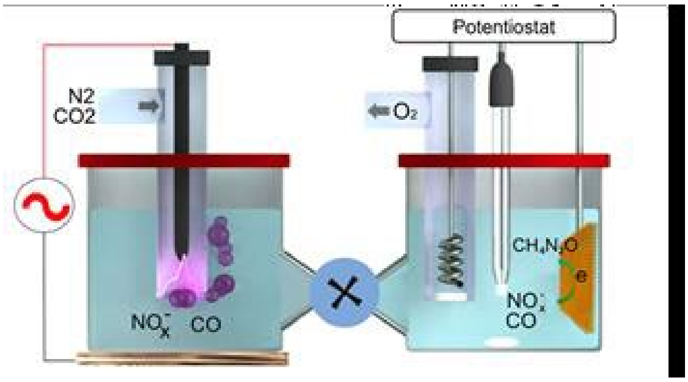

Figure. A proposed hybrid system of gaseous plasma activation and urea electrocatalysis from nitrogen and carbon dioxide

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Advancing Gold Hydrogen Production: Integrating Micro-CT and Deep Learning for Mineral Phase Analysis

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The exploration of gold hydrogen (H_2) as a low-carbon energy source has garnered increasing attention, particularly in regions of Australia where occurrences of gold H_2 have been reported. The oxidation of iron-containing minerals occurring underground, such as serpentinization, is considered one of the main contributors to H_2 production [1] (Eq 1). Besides the subsurface conditions (e.g., temperature, pressure, pH values), mineralogical factors play a crucial role in the H_2 generation process. Understanding and investigating the types of minerals involved, such as those participating in reactions, minerals that inhibit the rate of H_2 production, and potential catalytic minerals, along with their concentration, distribution characteristics, and co-location, is essential for developing reliable resource estimates and designing viable extraction methods. However, accurately identifying and mapping the 3D distribution of these minerals in subsurface rocks still remains a challenge.

$$\underset{\text{Olivine}}{Mg_{1.82}Fe_{0.18}SiO_4} + wH_2O \rightarrow 0.5\underset{\text{Serpentine}}{(Mg,Fe^{2+},Fe^{3+})_3(Si,Fe^{3+})_2O_5(OH)_4} + x\,\underset{\text{Brucite}}{(Mg,\ Fe)(OH)_2} + y\underset{\text{Magnetite}}{Fe_3O_4} + z\,H_2 \tag{1}$$

This presentation aims to integrate advanced imaging techniques and deep learning to enhance the characterization and analysis of minerals associated with subsurface H_2 generation reactions. It involves the fusion of image processing techniques from micro-CT, micro-XRF, and XRD, utilizing deep learning-based mineral phase characterization to construct the internal 3D structure of minerals within rock samples. This provides an accurate and consistent image analysis method for ultramafic rocks associated with gold H_2 production. These advancements offer valuable tools for assessing the potential of underground H_2 generation and provide critical insights into the mechanistic factors essential for the sustainable development of H_2 resources.

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A “Lightning” Platform for Green Synthesis

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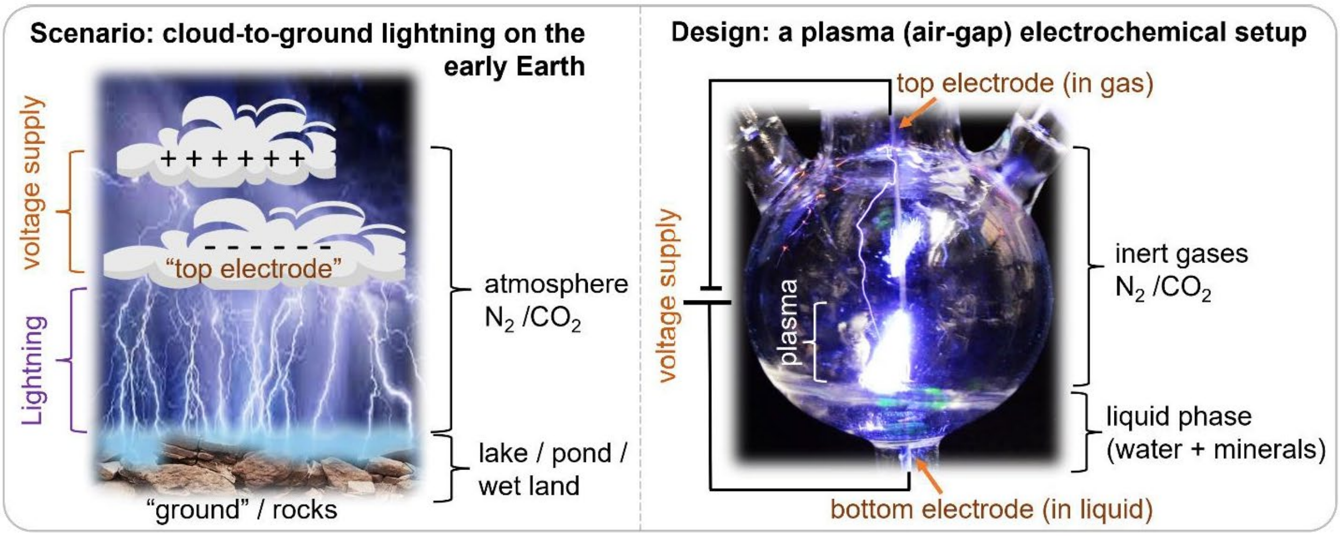
Inspired by cloud-to-ground lightning strikes on the early Earth, we designed a plasma (ionic gas) setup to mimic lightning-induced reactions, starting from simple and abundant reagents, such as N_2 and CO_2 in the air, inorganic minerals commonly found in rocks, and water. “Lightning”-type electrochemical reactions at air-water-ground interfaces lead to remarkable yields, with up to 40 moles of CO_2 being reduced into CO and formic acid, and 3 moles of N_2 being fixed into nitrate, nitrite and ammonia, per mole of transmitted electrons. Interfaces enable reactants (e.g., mineral particles and soluble electrolytes) to participate in radical and redox reactions, leading to higher yields compared to gas-phase only reactions, and faster kinetics compared to solution-only electrochemistry. Beyond exploring lightning and the chemical Origin of Life, this plasma electrochemical platform can contribute to green chemical synthesis, such turning air and water into nitrogen fertilizers and sanitizers with minimal carbon footprint.



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Revealing the role of vanadium-doped Ni_2P for enhanced urea oxidation

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Hydrogen (H_2) is a promising alternative to carbon-based fuels due to its environmental benefits and high energy efficiency[1]. While electrocatalytic water splitting is an eco-friendly method for hydrogen production, it is limited by the slow oxygen evolution reaction (OER) (1.23 V vs RHE)[2].

Urea, commonly used as a fertilizer, enters the environment through agricultural runoff and animal or human metabolism, disrupting the nitrogen cycle and ecosystems[3]. The electrochemical urea oxidation reaction (UOR) offers a green solution for urea treatment and can potentially replace the OER in hydrogen production due to its lower theoretical potential (0.37 V vs RHE)[4]. However, in real applications the required potential is higher than this amount due to its six electrons transfer process[5]. Therefore, efficient and cost-effective catalysts are needed to enhance the reaction rate.

In this study, V^{5+} ions are incorporated into the 3D structure of interconnected nickel phosphide nanosheets grown on nickel foam (V-doped Ni_2P/NF) to enhance the electrocatalyst's affinity for urea molecules. SEM confirms the nanosheet morphology (**Fig.** 1), and $V_{0.002}$-doped Ni_2P/NF exhibits superior electrocatalytic performance with a low onset potential (1.34 V vs RHE) toward UOR (**Fig.** 2a). Replacing OER with UOR reduces the overpotential required for 50 mA cm^{-2} by 160 mV (**Fig.** 2b). In situ Raman analysis reveals the formation of V-O bonds between V sites and urea molecules upon urea addition (**Fig.** 3). DFT calculations show higher urea adsorption energy on vanadium than on nickel sites (**Fig.** 4). Vanadium doping shifts the rate-determining step (RDS) from N_2 desorption to the first deprotonation, reducing the energy barrier from 2.62 eV to 2.03 eV (**Fig.** 5). In situ Raman and DFT calculations reveal that vanadium incorporation improves urea adsorption, reduces energy barriers, and enhances UOR efficiency.

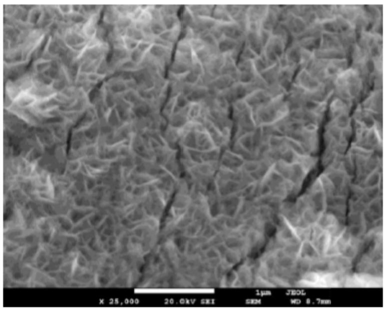

Figure 1. SEM images of the V-doped Ni_2P/NF

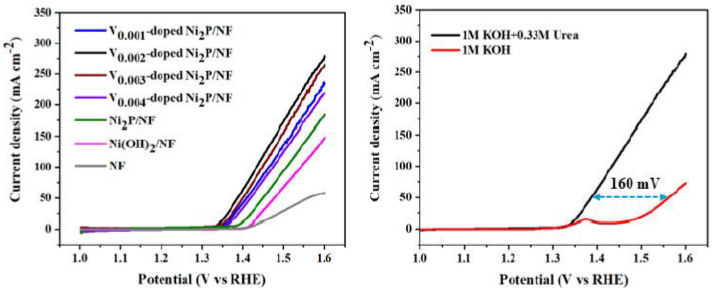

Figure 2. LSV curves of different prepared electrodes in 1 M KOH and 0.33 M urea and b) LSV curves of $V_{0.002}$-Ni_2P in 1 M KOH with 0.33 M urea and 1 M KOH

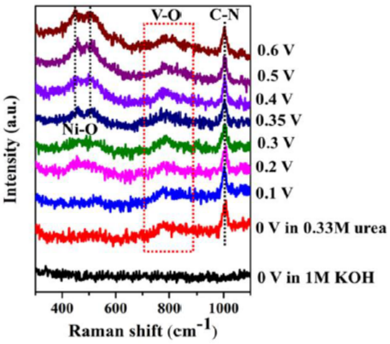

Figure 3. In situ Raman spectra of a) V-doped Ni_2P/NF

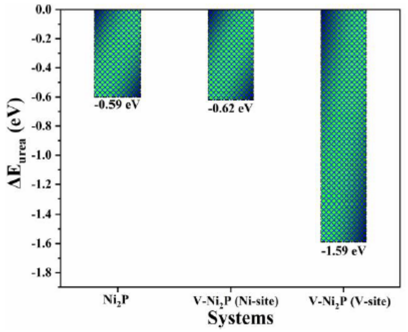

Figure 4. Urea adsorption on undoped and V-doped Ni_2P surfaces

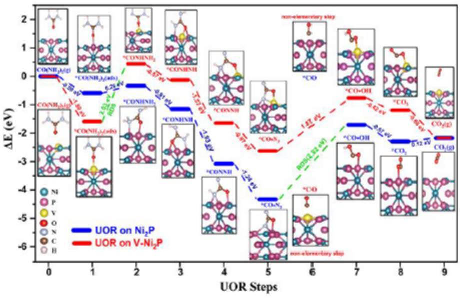

Figure 5. Comparative reaction energy (ΔE) profiles and optimized atomic configurations elucidate UOR pathways (in 9 steps) on V-doped Ni_2P/NF and Ni_2P/NF surfaces.

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High-throughput ammonia production from nitrate using liquid metal synthesised bismuth nano-catalyst

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In pursuit of a more sustainable future, the electrification of ammonia production through renewable resources stands out as a crucial strategy for effective decarbonisation. We present a novel method employing liquid metal-based synthesis to produce bismuth (Bi) nano- electrocatalysts, enabling efficient and sustainable ammonia production via nitrate electroreduction. This approach involves precipitating Bi from a gallium liquid metal alloy, yielding solution-processable Bi and its oxide with controllable nanostructures, including nanosheets, nanotubes, and nanoparticles. The synthesis of Bi nano-electrocatalysts is achieved through a metal expulsion method from a Ga-Bi liquid metal alloy, inducing interfacial processes that facilitate the expulsion of solute metal. This results in the precipitation of pure Bi metal atoms with tunable nanostructures and chemical properties. These high-quality Bi nano-electrocatalysts are then combined with graphene liquid crystals to form self-assembling layered electrocatalytic systems. By integrating 3D printing technology, we can precisely control the geometry, microporosity, and number of deposited layers in the electrocatalytic scaffold electrodes. This precision results in enhanced mass transport properties, increased durability, and prevention of catalyst detachment. As a result, the ammonia production rate achieved is 400 nmol.s^{-1}.cm^{-2}, with a Faradaic efficiency exceeding 90% and current densities surpassing 350 mA.cm^{-2}, demonstrating excellent scalability potential.

This study not only highlights a significant improvement in the ammonia production rate—by one order of magnitude—but also presents a robust and flexible solution for large-scale electrode fabrication. The combination of Bi nano-electrocatalysts, graphene liquid crystals, and 3D printing technology offers a promising pathway for the development of efficient and industrially viable electrocatalytic systems for ammonia synthesis.

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