MONASH University

WOODSIDE MONASH PARTNERSHIP 2022 ANNUAL REPORT

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IT IS THEIR ENTHUSIASM, EXCELLENCE AND DEDICATION THAT MAKES THE PARTNERSHIP SO EXTRAORDINARY…

– WOODSIDE MONASH PARTNERSHIP LEADERSHIP

2022 PERSONNEL

MONASH UNIVERSITY recognises that its Australian campuses are located on the unceded lands of the people of the Kulin Nations, and pays its respects to their Elders past, present and emerging

WOODSIDE MONASH PARTNERSHIP LEADERSHIP

2022 marks the seventh year of the Woodside Monash Partnership; a year characterised by substantial change, great successes and exciting new opportunities, where the Partnership continues to demonstrate its strength, adaptability, value and innovative nature.

The merger of Woodside Energy with BHP Petroleum in 2022 brought several important changes, as it significantly reshaped Woodside Energy's structure, priorities, and geopolitical context. Changes in Woodside Energy's structure allowed us to welcome back Voula Terzoudi, who played an important role in establishing the Monash FutureLab in 2016 and the establishment of the Woodside Monash Energy Partnership in 2019. Voula now acts as the Head of Australian Partnerships at Woodside Energy and will work closely with the Monash FutureLab and Energy Partnership over the coming years. Ruth Boardman was also welcomed as the new Focal Point for Data Science at Woodside Energy, with whom the FutureLab data science team aims to develop a strong and hopefully long-lasting relationship. Changes in geopolitical context have given the Partnership an international outlook, with many new opportunities resulting from the expansion to BHP Petroleum's base in Houston. The Woodside Monash Partnership team is delighted to have already met several new collaborators in person during their visits to Perth and Melbourne and look forward to visiting them in Houston and expanding the Partnership beyond Australian borders.

Among all this change, the Partnership has continued to produce outstanding results, such as bringing Woodside Energy's additively manufactured part request system (3DAM) online, being the first worldwide to identify the detrimental effect of nano-oxides on AM parts, delivering a fully functional Hydrogen network optimisation system for Woodside Energy's evaluation, leading the multi-million multi-industry and multi-university bid and subsequent establishment of the ARC Research Hub for Carbon Utilisation and Recyling and obtaining ARC Linkage funding for 3D printed catalytic monoliths for energy efficient carbon conversion. The unique nature and strength of the ongoing Partnership was recognised with the Monash Vice Chancellor's Award for Excellence in Enterprising Research. The excellent pipeline of students working on these multi-faceted projects have received external scholarships to further their work with the Partnership, and the Monash Carbon Capture and Conversion student team achieved the next milestone to secure the XPRIZE Carbon Removal.

It is important to highlight and recognise all academic and professional staff at both Monash and Woodside Energy, as well all the students and collaborators, whose work contributes to this Partnership. It is their enthusiasm, excellence and dedication that makes the Partnership so extraordinary. Special recognition goes to Jason Hill, whose constant presence, exceptional support and insightful advice has been key to navigating this year's challenges. In 2022, the leadership also welcomed Professor Murali Sastry as Global Partnerships Theme Leader. He brings significant experience in both materials science research and industry, having also held significant leadership roles abroad.

We hope you find this annual report as inspiring and interesting as the challenges the partnership tackled and the solutions it devised. In the meantime, our focus is now devoted to what promises to be the most exciting and rewarding year of the partnership so far. 2023, here we come!

JASON HILL

Woodside Monash Partnership, Manager

PROFESSOR MARIA GARCIA DE LA BANDA

Monash FutureLab Co-Chair, Information Technology

PROFESSOR PAUL WEBLY

Energy Partnership, Director

PROFESSOR CHRISTOPHER HUTCHINSON

Monash FutureLab Co-Chair, Engineering

PARTNERSHIP

MONASH FUTURELAB

The Monash FutureLab (est. 2016) is focused on solving today's challenges using the knowledge and technologies arising from additive manufacturing, materials engineering and data science. Materials engineering activities tackle major global challenges (such as corrosion) via new technologies and next-generation materials; advanced manufacturing and design activities focus on additive manufacturing as a disruptive technology; and the data science pillar applies advanced machine learning, optimisation and visualisation technologies to support sophisticated decision-making in areas such as plant design and energy network optimisation.

WOODSIDE MONASH – ENERGY PARTNERSHIP

The Woodside Monash Energy Partnership (est. 2019) is pioneering the energy transition to a lower-carbon future, with a three-pillar approach: affordable, bulk clean energy; carbon abatement; and thought leadership, aligning into the themes of New Energy Technologies, Carbon Capture, Conversion and Utilisation, and Energy Leadership. Activities centre on hydrogen production and carbon abatement to deliver new energy that is competitive with current markets, scalable for bulk energy transport, and value-adding through the creation of carbon products.

MONASH FUTURELAB

- 3DAM, Woodside Energy's additively manufactured part request system, was brought online at Woodside Energy with over a dozen requests lodged in the first quarter.
- The Detrimental effect of nano-oxides on the mechanical response of AM parts was identified for the first time and limits imposed on oxygen content of powder feedstock implemented to mitigate this potential issue. This discovery has implications for the worldwide field of AM, not only Woodside Energy.
- The FutureLab was awarded both the Engineering Dean's Faculty Award and Monash Vice Chancellor's Award for Excellence in Enterprising Research.
- Commercial additive manufacturing vendors were assessed and onboarded as manufacturing partners.
- A cooling fan blade was manufactured at Monash and supplied to site in under 1 week, superseding conventional manufacturing lead time by 6-8 weeks, de-risking a potentially significant production loss.
- A carbon fibre replacement ball valve was manufactured at Monash to replace an obsolete conventionally manufactured cork part.
- FutureLab prototyped and manufactured 50+ parts for Woodside Energy's robotics team, the majority in assistance of the Spector project.
- FutureLab commenced activities on the underlying science and technology of Wire Arc Additive Manufacturing (WAAM) parts to increase the size of components that can be fabricated by Woodside Energy.
- A new Woodside Energy data science focal point, Ruth Boardman, joined the FutureLab team and Voula Terzoudi was welcomed back as Head of Partnerships Australia.
- The hydrogen network optimisation system was expanded to model new plant capabilities (incl. multiple electricity providers, gas/liquid production, liquid storage, unit turndown, boiloff, etc.) and their associated effects on the network. The scalability and robustness of the system itself was significantly improved and a User Interface was developed to allow users to obtain and visually compare a set of diverse (near optimal) solutions for a given scenario. The complete system has been installed in a Woodside Energy server to be evaluated.
- An ARC Linkage Project was awarded for 3D Printed Catalytic Monoliths for Energy Efficient Carbon Conversion in partnership with the Woodside Monash Energy Partnership, utilising the FutureLab's additive manufacture design and prototyping capabilities.
- Two projects investigating the decommissioning of flexible flowlines and umbilicals were launched in collaboration with the Chemical and Biological and Civil Engineering faculties.
- A method was developed to significantly speed up optimal 3D pipe routing for open areas commonly found in LNG plants or subsea scenarios.

FutureLab students in the lab

Vice Chancellor's Award for Excellence in Enterprising Research

ENERGY PARTNERSHIP

- Professor Murali Sastry joined the Woodside Monash Energy Partnership as the Global Partnerships Theme Leader.
- Monash University, Curtin University, University of Queensland, Queensland University of Technology and the Australian National University, alongside 21 industry partners and 3 international centres, were awarded the ARC Research Hub for Carbon Utilisation and Recycling by the Australian Research Council. Woodside Energy is the largest industrial partner within the initiative and builds on early work by the Partnership.
- ARC Linkage Project awarded for 3-D Printed Catalytic Monoliths for Energy Efficient Carbon Conversion in partnership with FutureLab.
- Monash University and RMIT, awarded the AI for Clean Energy and Sustainability by CSIRO as part of the Next Generation Graduates Program, where the Woodside Monash Energy Partnership is a key industrial partner.
- Monash Carbon Capture and Conversion achieves milestone to secure full $250K USD award by XPRIZE Carbon Removal.
- The Partnership, alongside, Engie Impact, and Nikkiso Clean Energy & Industrial Gases, delivered a feasibility study for the Victorian Renewable Liquid Hydrogen Supply Hub in the Monash Precinct, supported by the Department of Energy, Environment and Climate Action (Victorian Government).
- Through the Partnership, Woodside Energy establishes an industry research partnership with the Exciton Science Connect Program as part of the ARC Centre of Excellence in Exciton Science, for Ultra-low-cost Photovoltaics.
- Chemical and Biological Engineering PhD student Liam Turner, and PhD Student for LH2 Boil-off Gas Management program, was awarded the Fulbright Future Scholarship, in support of a 12-month placement at the HYPER Lab in Washington State University.
- Materials Science and Engineering PhD student Jefferson Lam, and PhD student for the Ultra-low-cost Photovoltaics program was awarded the Australian Academy of Technological Sciences and Engineering's Ezio Rizzardo Polymer Scholarship for 2022 by ATSE.
- Chemical and Biological Engineering PhD student Garv Bhardwaj, and PhD student for CO2 Conversion by Plasmonic Catalysts program was awarded Catalysis Summer School Bursary by The Institution of Chemical Engineers (IChemE) and the Andrew Legacy Scheme.
- PhD student, Garv Bhardwaj, and 5th year WMEP research project student (and Operations Assistant), Evangeline Leong, alongside student colleagues, Bennet Sam Thomas (incoming Monash Capture and Conversion CEO), Nithiya Pathmasiri, and Daniel Feltham won third place at Chemeca Future Fuels CRC Student Hackathon 2022.
- Director of the Woodside Monash Energy Partnership, Professor Paul Webley, and President of the International Adsorption Society, delivered keynote talk to the 14th International Conference on the Fundamentals of Adsorption in Broomfield, Colorado, USA.
- Woodside Monash Energy Partnership and National Centre of Excellence in Carbon Capture and Utilisation (NCoE-CCU) at Indian Institute of Technology Bombay (IITB), co-facilitate Global Energy Futures Conclave at IITB-Monash Research Academy.

Jefferson Lam awarded the Australian Academy of Technological Sciences and Engineering's Ezio Rizzardo Polymer Scholarship for 2022 by ATSE

MONASH FUTURELAB

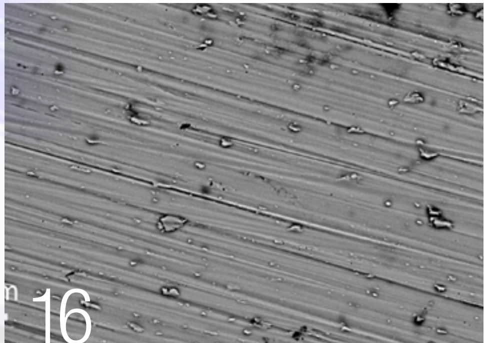
MONASH FUTURELAB
STRATEGIC RESEARCH THEMES

ADDITIVE MANUFACTURING

DELIVERING ADDITIVE MANUFACTURING (AM) PART SUPPLY AS 'BUSINESS AS USUAL' AT WOODSIDE ENERGY

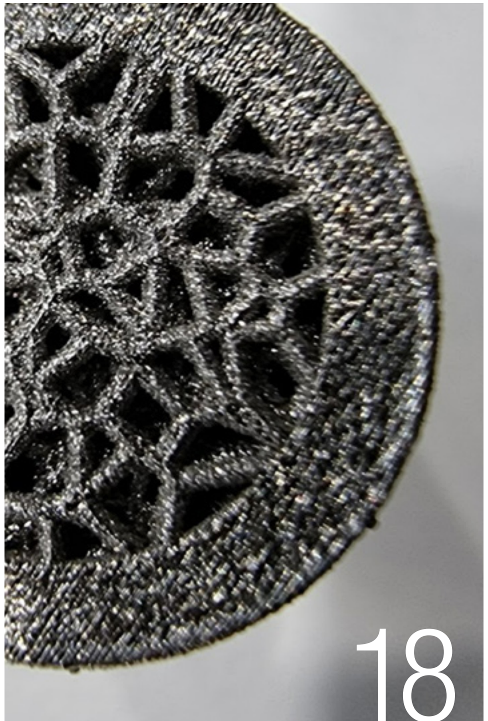
DATA SCIENCE

USING DATA SCIENCE SOLUTIONS TO OPTIMIZE PLANT DESIGN AND OPERATION



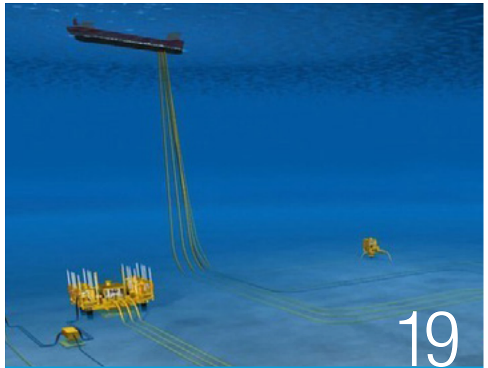
MATERIALS FOR NEW ENERGY

DESIGNING NEW MATERIALS FOR A HYDROGEN ECONOMY



ENERGY PARTNERSHIP COLLABORATIONS

ASSISTING WMEP PROJECTS WITH PART DESIGN AND PROTOTYPING



DECOMMISSIONING

TACKLING SEPARATION AND PROCESSING OF DECOMMISSIONED FLEXIBLE FLOWLINES

PROJECT IN FOCUS

EXTENDING ADDITIVE MANUFACTURING (AM) IMPLEMENTATION

2021 concluded with a significant success for the Woodside Monash FutureLab.

A 316L stainless steel monoflange, 3D printed at Monash, was installed offshore in hydrocarbon service; a culmination of almost 7 years of materials and manufacturing research, attempting to answer the question: Can additive manufacturing be used as spare part supply in the energy sector?

The monoflange case study answered this question with a resounding yes.

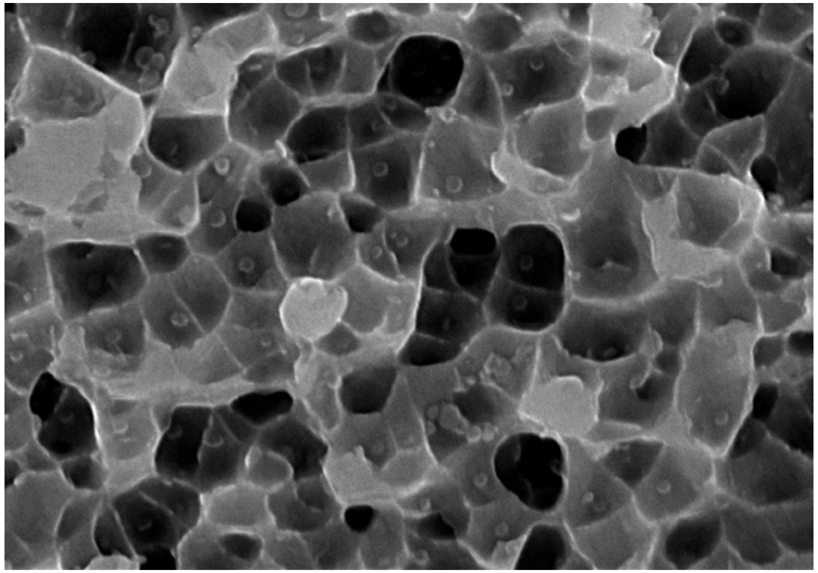
The 2022 FutureLab research program aimed to broaden the implementation of AM, with Dr Lee Djumas seconded to Woodside Energy, for this purpose.

On the ground at Woodside Energy,, a pathway to AM part manufacture was set up through the 3DAM part request system and over a dozen requests were lodged in the first quarter. Parts that require design adjustments, have become obsolete, or have exceptionally long lead times (i.e. up to 2 years), pose a significant business case for the use of AM. However, design for AM still requires understanding of AM capabilities, highlighting the need for additive manufacturing education and credentials to be offered to suited Woodside Energy personnel.

The expanding AM program could also no longer simply rely on the handful of printers stationed at the Monash FutureLab in Melbourne. Commercial additive manufacturing vendors were assessed with a selection of trial parts and materials qualification challenges. These investigations highlighted the required chemical purity of feedstock powders, leading to a journal publication and renewed pressure on metal powder manufacturers to ensure feedstock quality.

Quality control has remained a focus of the FutureLab AM research program. The types and potential mechanical and electrochemical effects of printed materials comprise two of the current PhD programs in the FutureLab. The introduction of a new 3D printer, with associated print monitoring system, installed at the University of Western Australia Techworks group, significantly enhances this work and furthers the successful collaboration thus far between Monash and UWA, alongside Curtin University.

The future of the AM program will explore new AM technologies and materials. Wire Arc Additive Manufacturing (WAAM) will likely play an integral role in large part manufacture (e.g. tonnes of material), with successes already reported by Shell and Chevron. Meanwhile, materials innovation remains a pillar of the Woodside Monash FutureLab and research into new alloys continues to gain a competitive advantage in the AM metals space and beyond, whilst simultaneously ensuring that suitable and reliable materials will be available for a future hydrogen energy market.



Nano-oxides on the fracture surface of an AM Ni alloy.

LEADERSHIP

MONASH FUTURELAB LEADERSHIP

(Back row, L to R):

Dr Lee Djumas
Additive Manufacturing Subject Matter Expert
(Woodside Energy)

Dr Erin Brodie
Woodside FutureLab Research and Innovation Manager
(Monash University)

Michael Brameld
Principal Materials Engineer
(Woodside Energy)

Dr Sebastian Thomas
Corrosion Lead
(Monash University)

(Front row, L to R):

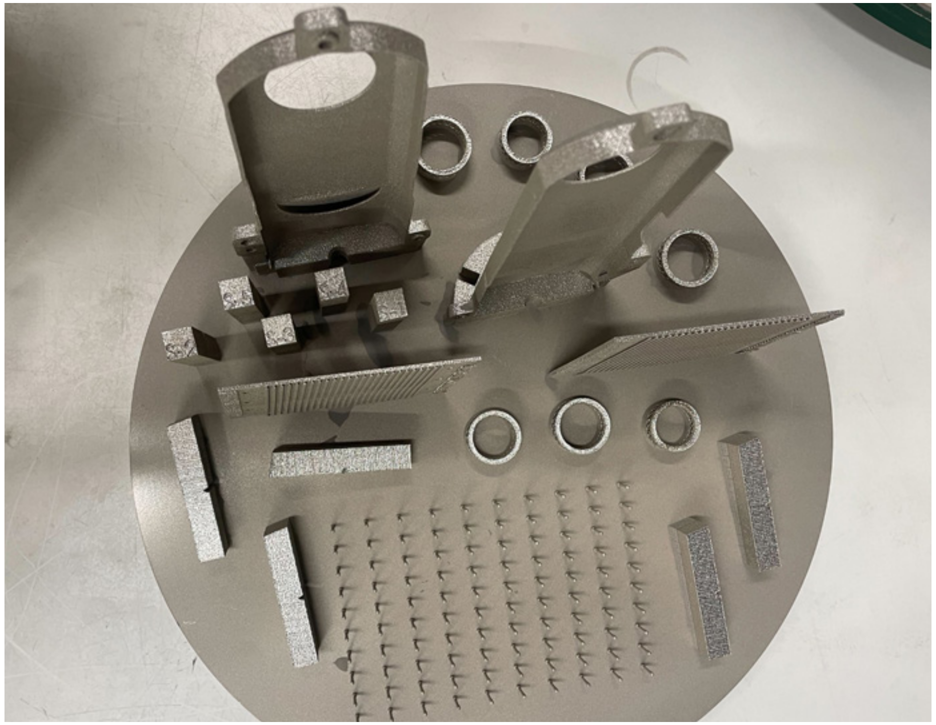
Jason Hill
Monash Woodside Partnership Manager
(Woodside Energy)

Professor Maria Garcia de la Banda
Co-Chair and Data Science Lead
(Monash University)

Professor Christopher Hutchinson
Co-Chair and Materials Lead
(Monash University)

Voula Terzoudi
Head of Partnerships Australia
(Woodside Energy)

AM IMPLEMENTATION



CREATING THE AM PART PATHWAY

- Additively manufactured part request system, 3DAM, brought online at Woodside Energy, with over a dozen requests lodged in the first quarter.
- Preferred AM vendors assessed and onboarded for consistent part supply.
- Broadened relationships with metal powder manufacturing companies, securing the supply chain for Australian AM production capabilities.
- Ensured part quality across a range of different 3D printing systems.
- Compilation of the Woodside Energy Engineering Standard: Additive Manufacturing.

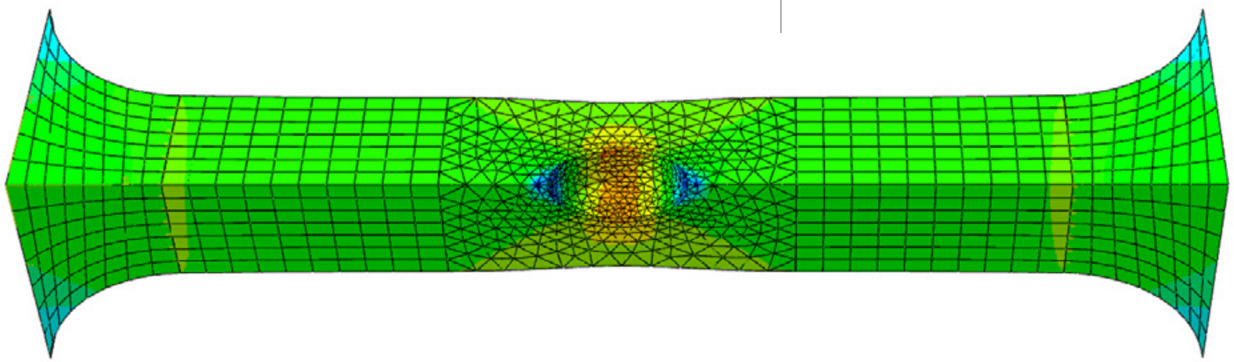
FAST TURNAROUND AM POLYMER PARTS

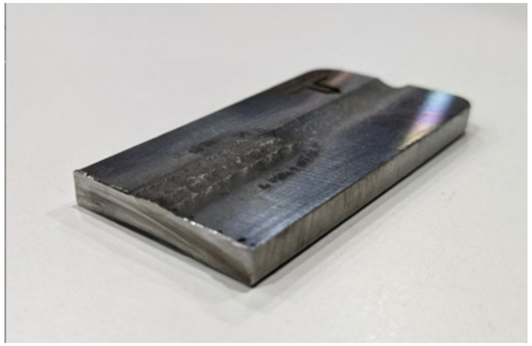
- Cooling fan blade, 3D scanned by vendor, manufactured at Monash and supplied to site in under 1 week. Fast turnaround superseded conventional manufacturing lead time by 6-8 weeks, de-risking significant production loss.
- Fast prototyping of carbon fibre composite hollow ball to replace a cork ball valve unable to be conventionally sourced.
- Over 50 parts, ranging from walkie talkie holders to camera mounts, manufactured for Woodside Energy's robotics team, assisting with the Spector project.

EXTENDING AM AT WOODSIDE ENERGY

EFFECTS OF PRINT ANOMALIES ON ELECTRO-CHEMICAL & MECHANICAL PERFORMANCE

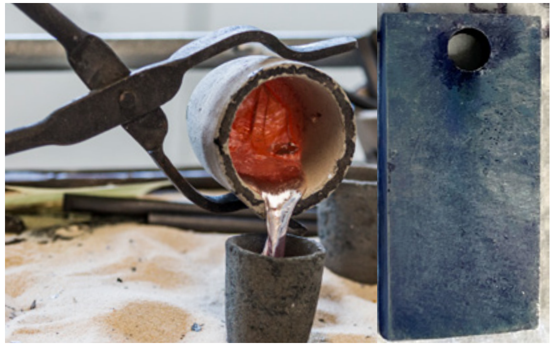
- An FEA simulation was constructed to visualise internal stress and strain concentrations surrounding potential anomalies in virtual tensile samples. The simulation was validated by introducing matching artificial anomalies to 3D printed tensile samples.
- To understand the corrosion of potential near-surface and surface anomalies, which tend to have significantly rough surfaces, polarisation tests were conducted on as-built and finished surfaces to measure the difference in passive film breakdown.
- In-situ monitoring on the new EOS M 290 at the University of Western Australia was paired with X-ray CT data to detect real and artificial anomalies to assess the suitability of current detection capabilities of in situ print monitoring.





BROADENING AM TO LARGE PARTS AND PART REPAIR

- Investigating Wire Arc Additive Manufacturing (WAAM) as a method for large part manufacture (eg. tonnes of material) through mechanical and eletro-chemical testing of a range of potential alloys.
- Exploring cold spray as a method of repair for thermally sprayed aluminium parts.
- Welded AM material assessed across multiple alloy classes to ensure welding as a suitable joining method, widening the implementation potential for AM parts.



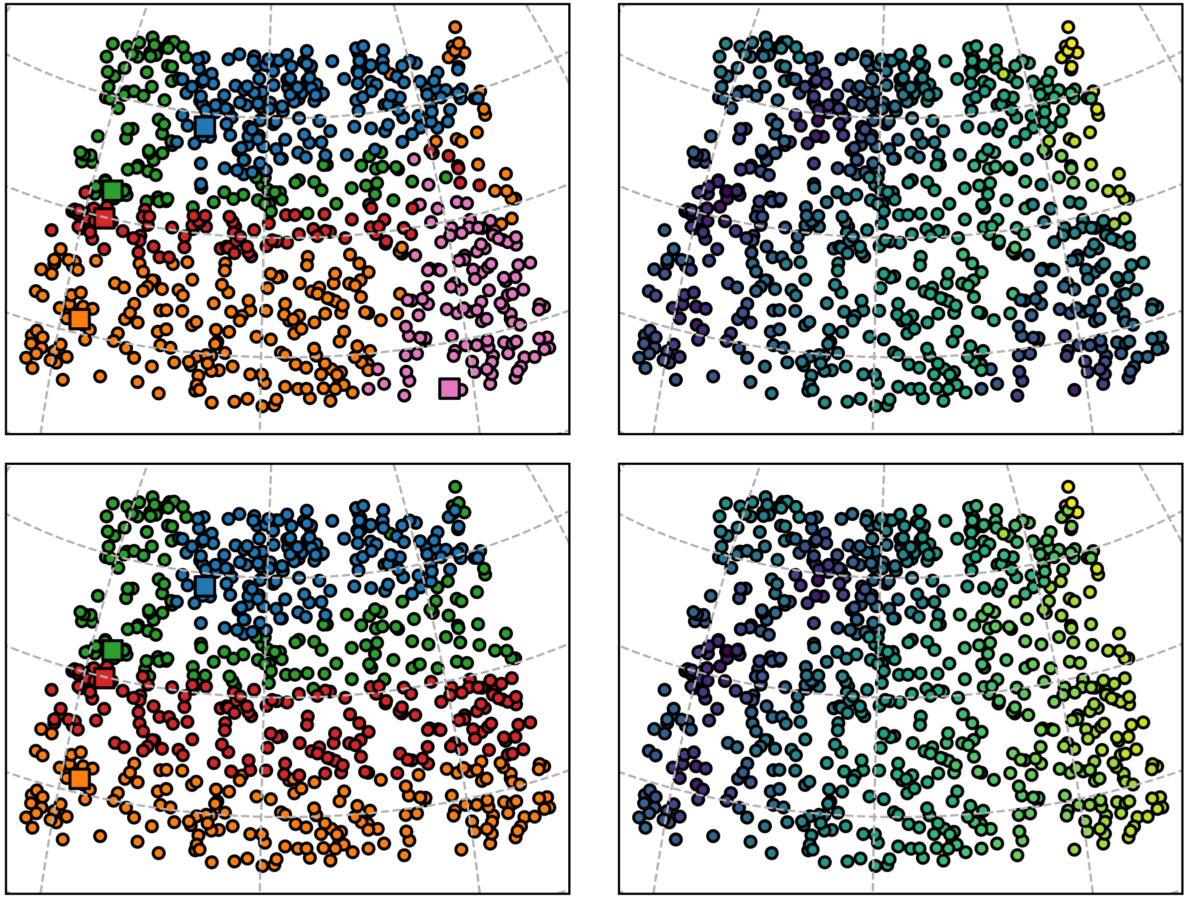
AM ALLOY DEVELOPMENT FOR NEW ENERGY APPLICATIONS

- Brand new alloy composition created to cover all service requirements (cryogenic temperatures and highly corrosive environments) and to reduce cost and time of acquiring, developing, servicing and joining separate materials.
- New composition tested mechanically and chemically against existing alloys certified for AM.
- Further iterations to the new alloy composition made and sheet cast and rolled in the US.
- In parallel to the above, a commercially available tungsten containing alloy test manufactured by L-PBF to assess the laser processing capabilities of tungsten containing alloys.

DATA SCIENCE

H2 NETWORK OPTIMISATION CHALLENGE

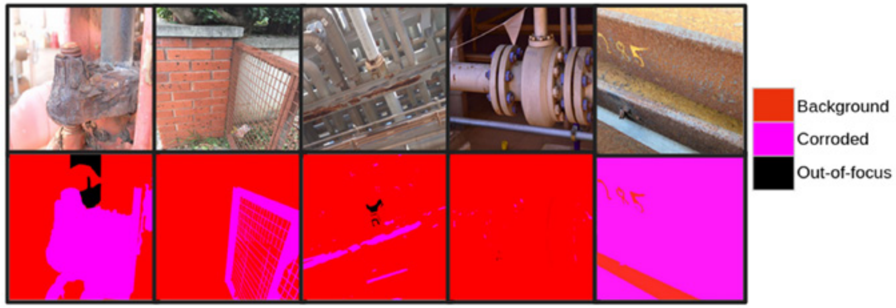
- Expanded the interactive optimisation/visualisation software system for optimising H2 networks to include different electricity providers, gas and liquid storage, boiloff, exact latitude/longitude locations rather than state, minimum and maximum production capacity constraints per plane, production change rates for liquefaction units, and the map style requested by Woodside Energy.
- Significantly improved the efficiency of the system to handle 700+ demand locations; achieved by modifying the system to use data and/or constraint approximations that allow it to find solutions of very similar quality, orders of magnitude faster.
- Added the capability for users to provide a diversity criterion (e.g.different locations for supply plants, significantly different production capacity, etc.) to obtain a given number of near optimal solutions.
- Implemented a Continuous Integration software development process that ensures the solutions obtained by the system are correct; achieved by developing several new network models whose solutions must coincide for all available benchmarks, and running the process every time the system is modified.
- Implemented a sophisticated User Interface that allows users to explore each solution in detail (by plant, by component, or as a network), to modify the input data obtaining alternative solutions, to obtain diverse solutions for the same input data, and to compare them.
- System demonstrated to the Woodside Energy USA team and fully functioning prototype installed in a Woodside Energy server to be tested and evaluated by the Woodside Energy team.

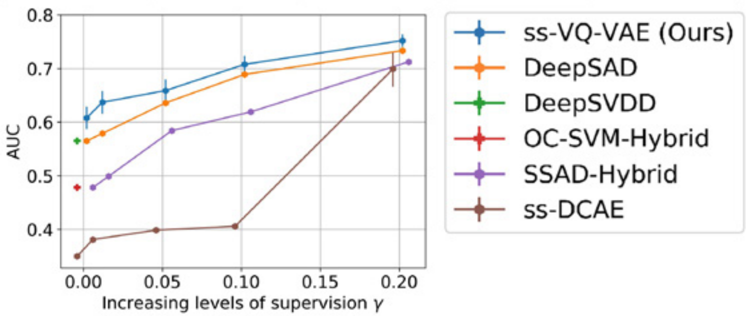


Left: hydrogen plant locations (squares) of an approximate (top) and an exact (bottom) solution and the locations supplied by the plants (circles in the plant's colour). Right: cost incurred by the demand locations from dark blue (cheapest) to yellow (most expensive).

MACHINE LEARNING FOR CORROSION DETECTION

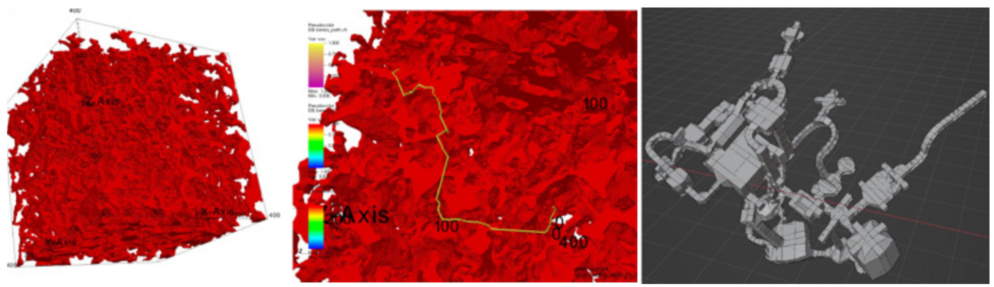
- Received access to 4 data sets of image-spheres from the North West Shelf project (Karratha Gas Plant, North Rankin A, North Rankin B, Goodwyn A) and extracted a large set of standard images from it to increase our (unlabeled) corrosion data set.
- Explored the use of VQ-VAE neural networks for anomaly localisation at the image pixel level, as they are suitable for learning from unlabeled data with quality on par to GANs but without the risk of model collapse, easier training and better explainability.
- Implemented a semi-supervised VQ-VAE neural network with a novel anomaly score calculation and performed an extensive evaluation of its supervision/accuracy trade-off on several datasets, significantly outperforming other state-of-the-art methods. Paper submitted to IEEE ICME conference.





PIPE ROUTING

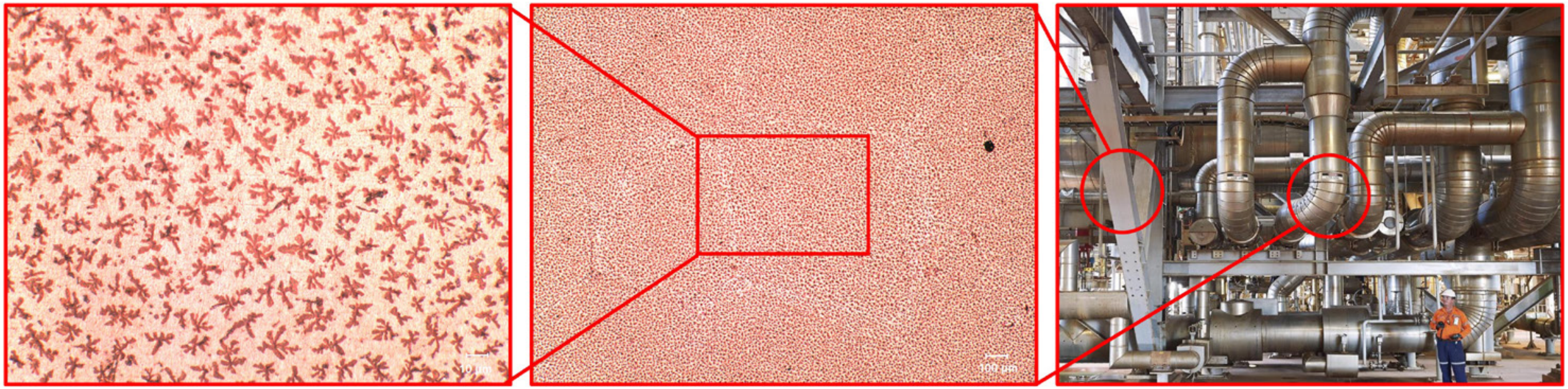
- Extended the 2D state-of-the-art Jump Point Search (JPS) algorithm used widely in the gaming industry to 3D and made it suitable for computing pipe routes (as opposed to classical paths in 3D game path finding); achieved by developing powerful new path-symmetry breaking rules capable of dealing with both confined and large open spaces.
- Proved that the Corner-Cutting methods proposed by others in the literature are non-optimal, may produce incorrect solutions, and are difficult to repair, confirming the need for the more complex rules used by our 3D JPS algorithm.
- Developed three large datasets to be used by the research community for evaluating progress in the new area of 3D path finding algorithms; our creation method ensures the datasets are complex, diverse and fair.
- Results published (Nobes, Thomas K., et al. "The jps pathfinding system in 3d." Proceedings of the International Symposium on Combinatorial Search. Vol. 15. No. 1. 2022.)



MATERIALS FOR NEW ENERGY

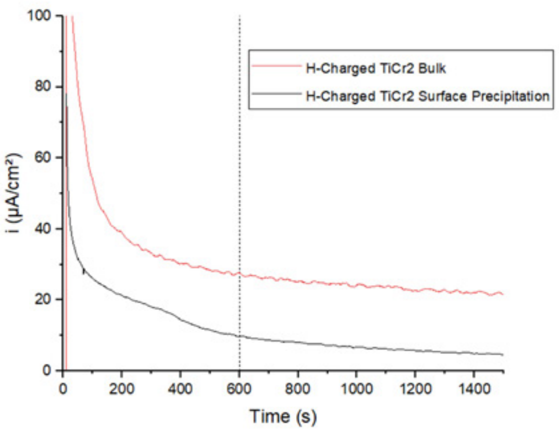
SMART ENGINEERING ALLOYS

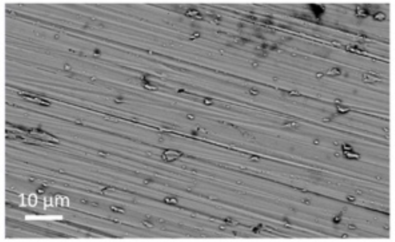
- Investigating smart structural alloys which could provide scalable solutions to CO_2 conversion, hydrogen storage and anti-microbial surfaces.
- A trial alloy was arc melted and heat treated to create surface precipitates specifically suitable for hydrogen absorption. Lower hydrogen diffusion from the sample with surface precipitate indicated trapping of H within the surface precipitates. To be validated with other characterisation techniques.
- ARC Early Career Industry Fellowship grant application submitted to further support this work. Outcome expected Q2 2023.

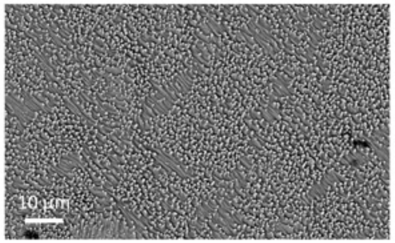


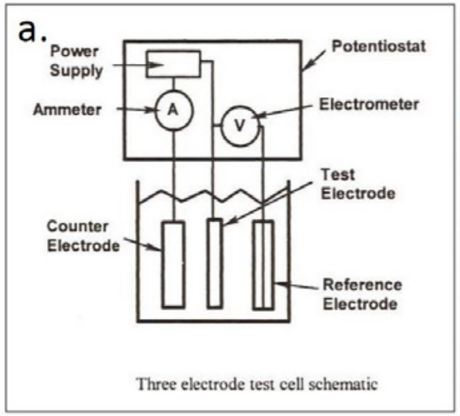
HYDROGEN EFFECTS IN METALS

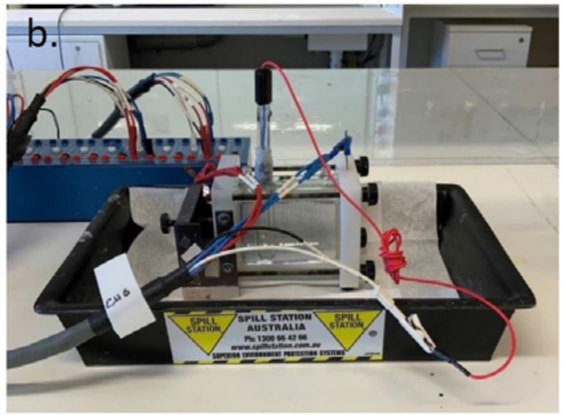
- Exploring hydrogen induced damage, caused when hydrogen atoms diffuse into metals, resulting in embrittlement.
- AM 316L assessed in direct comparison to conventionally manufactured 316L for hydrogen absorption and desorption.
- Samples mechanically deformed to assess hydrogen impact during damage.
- Project in collaboration with and running simultaneously to a Curtin University PhD project, exploring the effects of hydrogen on conventional and AM Ni alloys.

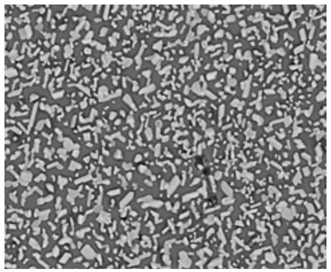


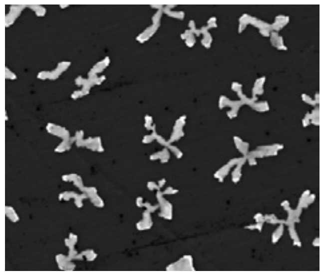


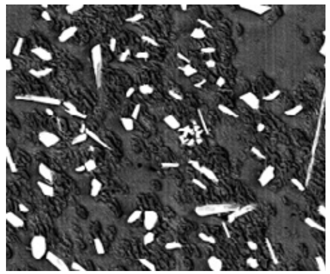








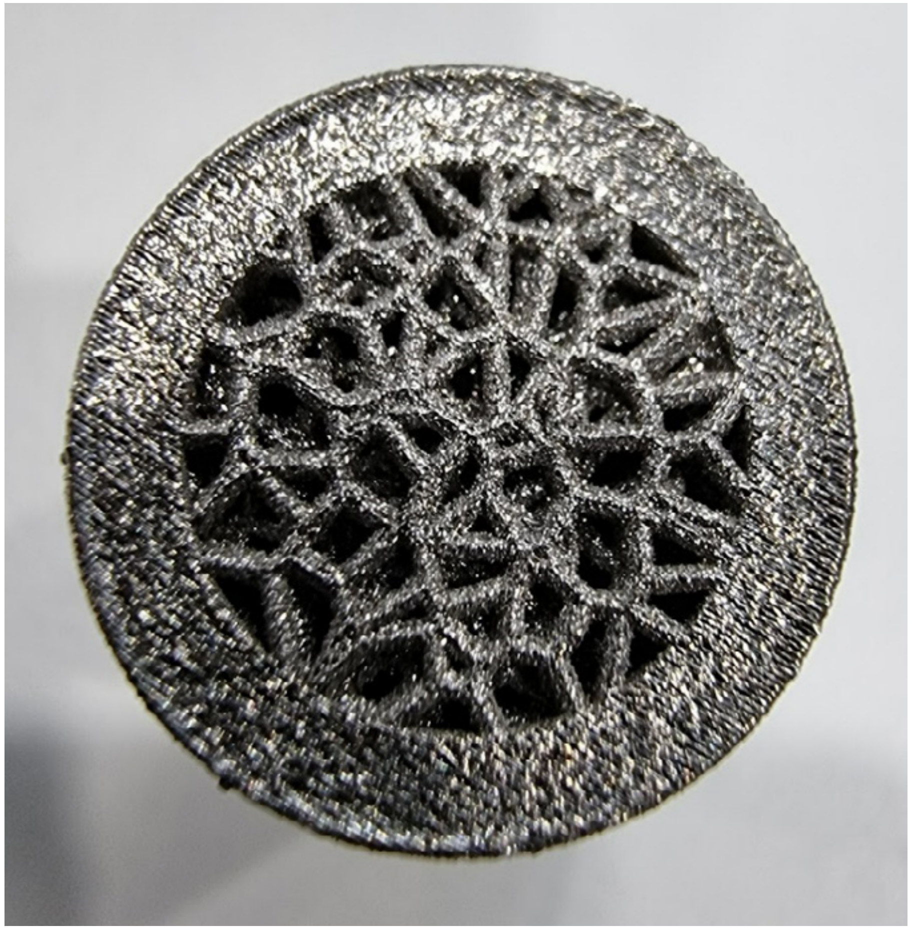




ENERGY PARTNERSHIP COLLABORATIONS

FAST PILOT PLANT PART PROTOTYPING AND DESIGN

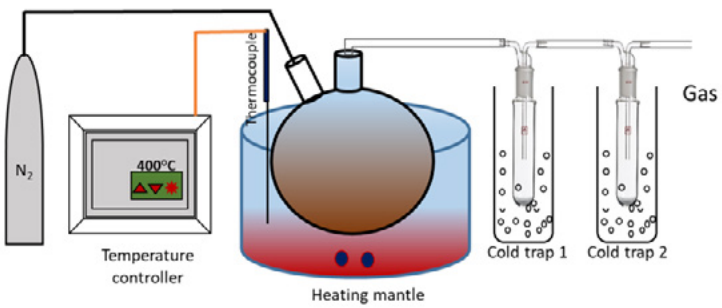
- Bacteria counting device prototyped and manufactured to assist the conversion of waste gasses into sustainable animal feeds.
- Linkage Project awarded for $405,591 over 3 years (2023-2025 inclusive) for '3D Printed Catalytic Monoliths for Energy Efficient Carbon Conversion', using FutureLab AM design and prototyping capabilities.
- AM design used to explore high surface area scaffold designs for new catalysts.



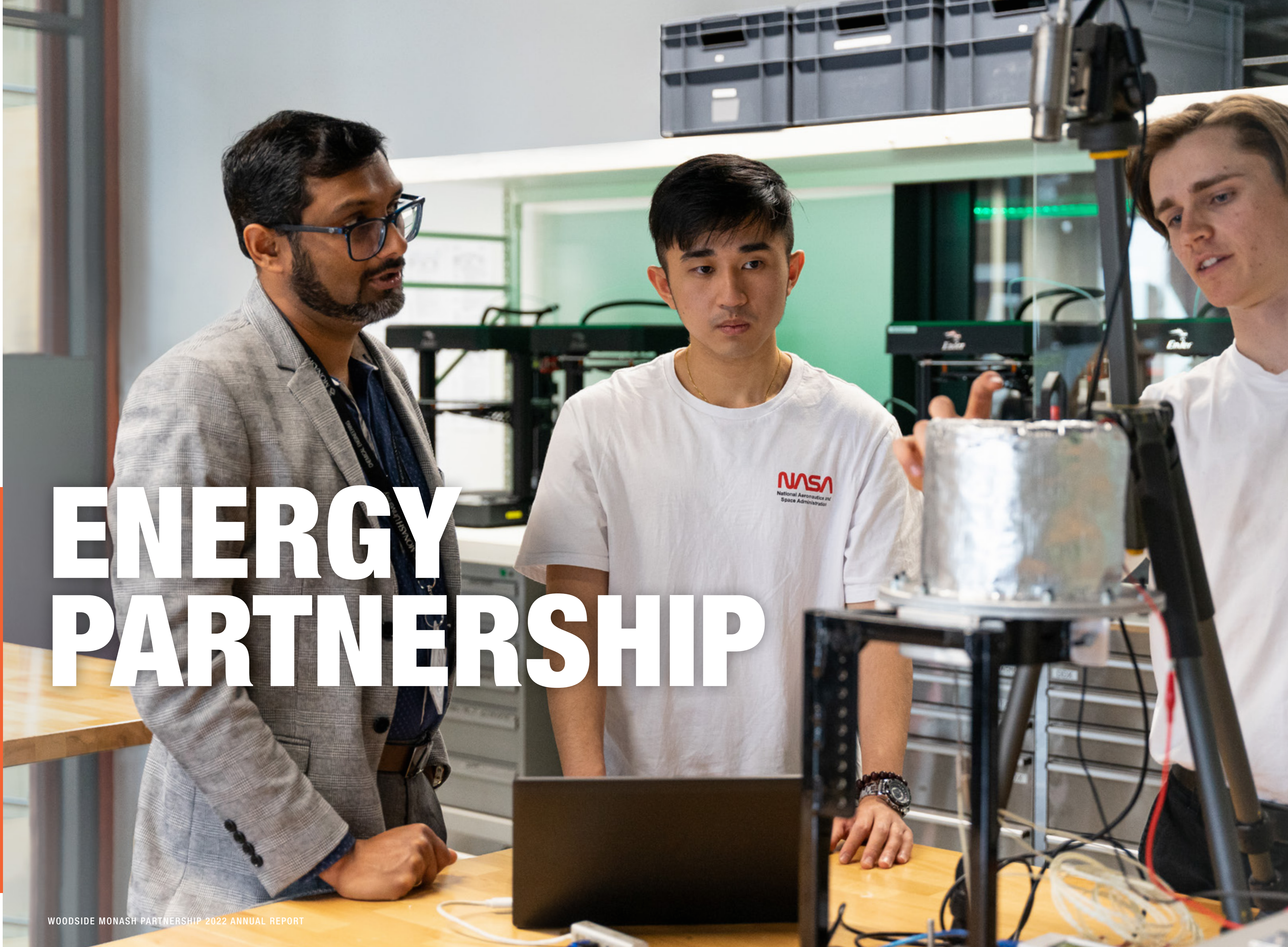
DECOMMISSIONING

SEPARATING AND PROCESSING OF FLEXIBLE FLOWLINES

- Image digitialisation for pipe workability established, recognising the difference between non-damaged and damaged pipelines, to ensure the success of robotic material separation.
- Large pilot pyrolysis rig constructed for processing polymer at atmospheric pressures and circularity of processing confirmed. Further samples required to ensure robustness of rig across a variety of flowline types and sizes.
- Hosted academics from Melbourne University, RMIT and Swinburne to form a decommissioning thought hub in Melbourne.



ENERGY PARTNERSHIP



ENERGY PARTNERSHIP STRATEGIC RESEARCH THEMES

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NEW ENERGY TECHNOLOGIES

HIGH-EFFICIENCY AND LOW-COST SOLUTIONS TO GENERATE, STORE, AND EXPORT CARBON NEUTRAL ENERGY, INCLUDING HYDROGEN AND ITS CARRIERS

CARBON CAPTURE, CONVERSION AND UTILISATION

COMMERCIALLY SUSTAINABLE SOLUTIONS THAT REDUCE ATMOSPHERIC CARBON DIOXIDE EMISSIONS THROUGH CHEMICAL, THERMAL, AND BIOLOGICAL APPROACHES

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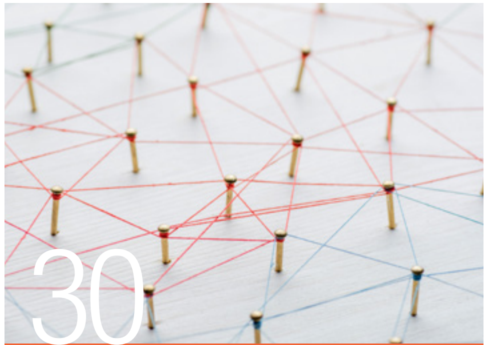

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ENERGY LEADERSHIP

UNDERSTANDING AND ENABLING THE INTERPLAY OF ECONOMICS, ENERGY SECURITY, POLICY AND GOVERNANCE ON THE TRANSITIONING ENERGY SYSTEM, INCLUDING CARBON MARKETS

LEADERSHIP AND THEME LEADERS

LEADERSHIP TEAM

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Climate Strategy & Policy
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Graduate Process Engineer
(Woodside Energy)

PROJECT IN FOCUS

ANALYSING CHANGE FOR A LOWER CARBON FUTURE

In October 2022, a United Nations report warned that only an "urgent system-wide transformation" to a global low-carbon economy will deliver the huge cuts to greenhouse gas emissions needed by 2030 if we are to avert the worst impacts of global warming.

But while there is agreement on the scale of cuts needed, there is no agreement on how to get there. Countries have different plans and priorities, reflecting the different pressures they are under, whether it is internal politics, energy dependencies, and uneven finances, resources and living standards.

Meeting this critical global challenge is going to depend on whether these disparate approaches and pressures can be co-ordinated to deliver the scale of cuts needed. So, what is driving the differing approaches around the world and what scope is there to better co-ordinate them?

IN-COUNTRY CLIMATE POLITICS

Internal "climate politics" is a driving force behind the different approaches being taken by national governments. The rising electoral power of "Green" parties in Europe is creating pressure on government to adopt more proactive climate policies. In France, 25 per cent of 18 to 24-year-olds voted for the Green Party in the 2019 European Parliament elections, while in Germany more than a third of young people voted Green.

In June 2019 Finland's ruling coalition, which included the Green Party, plans to achieve "carbon neutrality" by 2035, ten years earlier than Finland's original plan. Denmark makes full use of renewable energy, Germany has been making serious efforts to develop renewable energy with the introduction of its "Climate Action Law" and Climate Action Programme 2030.

Further afield Canada has been able to implement a carbon tax to encourage reductions in emissions, while Japan and South Korea have released detailed development roadmaps for hydrogen energy.

In the United States, while the "Green New Deal" is supported by 104 members of Congress and was backed by four contenders for the Democratic presidential nomination in 2020, the pressure on government to take decisive action to reduce emissions is weaker and diluted across different state governments.

In 2019, Australia's National Hydrogen Strategy was adopted, with hydrogen energy rising to the level of a national strategy. The strategy is expected to pave the way for Australia's hydrogen economy, thereby enhancing Australia's energy security, creating a large number of jobs, and establishing a multi-billion-dollar export industry.

The Chinese government is increasingly determined to address the climate change issues and is increasingly investing in clean technologies. But getting buy in from businesses in this manufacturing driven economy remains a formidable challenge.

THE POLITICS OF NORTH AND SOUTH

"Climate politics" in the international arena also operates between high and lower-income countries, the global north and global south respectively. For a long time, people have been discussing the degree to which the north should be expected to carry a higher burden than the south when it comes to cutting emissions.

For lower-income nations it is critical that they strike a balance between sustainability and affordability in their efforts to achieve lower carbon, which means that a multi-step, incremental and transitional approach would be more effective than a one-step, radical and transformational approach.

CLIMATE BUSINESS

Climate Politics and climate business often go hand-in-hand – there is money to be made as well as spent in the transition to a lower carbon economy, and this relationship between business and government varies around the world.

Financial groups like BlackRock Capital, have aligned with different governments to invest in carbon reduction programs, while clean energy companies are seeking to expand and capitalise on renewable or low-carbon technologies, often facilitated by varying government financial incentives.

TECHNOLOGICAL ADVANCEMENT

Technological progress is profoundly changing the way energy is produced and consumed and opening up new avenues for achieving low-carbon economies that may be universal, but which also may suit some countries more than others. For example, building on its manufacturing strength and backed by the government, China has developed a globally competitive solar panel industry and is making fast progress in electric vehicle design and production.

Breakthroughs in oil and gas production technology, big data, artificial intelligence, virtual reality, the Internet of things, blockchain, and other new technologies, as well as nano, graphene and other new materials, are driving the energy industry to transform to high-efficiency, green, low-carbon, digital, and intelligent energy production and supply.

CULTURAL TRADITIONS

One of the less obvious drivers behind the differing approaches to reducing emissions are cultural traditions. A 2020 study found that local culture had an important impact on energy consumption across 28 countries.

For example, a culture like that is centred on individual car ownership will generate higher carbon dioxide emissions, whereas cultures that embrace public transport can be expected to generate less emissions.

Solar home systems can effectively replace fossil fuel, but it is difficult for some families in religious countries to accept it because electric cookers lack the ‘natural’ characteristics such as flame and smoke. While smoke in some locations also has the practical use of keeping the insects out of homes, flames brings light which is of spiritual significance.

CLIMATE CHANGE AND LOWER CARBON TRANSITION – TOWARDS A COMMON GLOBAL AGENDA?

This backdrop of different and sometimes competing agendas and circumstances among countries is one of the reasons why significant reductions are proving difficult to achieve. The response of countries to the COVID-19 pandemic is emblematic of this.

The pandemic prompted governments around the world to make large investments in economic recovery. If there had been more international co-ordination on how to invest recovery funds governments could have agreed to invest in low carbon economic growth, like technology, renewable energy, and the infrastructure and jobs of a low-carbon economy. Instead countries have generally focused simply on driving a recovery as fast as possible, including a recovery in emission levels.

On the plus side, an important outcome at the recent COP27 meeting in Egypt was the commitment to create a loss and damage fund that is expected to provide funds to lower income countries especially vulnerable to the impacts of climate change. While the details are yet to be worked out, it is this sort of coordination on policy that is badly needed.

Whether we achieve a fair and timely transition to a global lower carbon economy is ultimately contingent upon the ability of governments and citizens to navigate our differences. And key to that is appreciating these differences in the first place.

If you are interested in reading more on the topic, please read Wang, J. T., Zhou, Y. and Cooke, F. L. (2022). Low-carbon economy and policy implications: A systematic review and bibliometric analysis. Environmental Science and Pollution Research, 29(43), 65432–65451.

This article originally appeared on Lens, Monash University’s thought leadership website.

PARTNERSHIP TEAM

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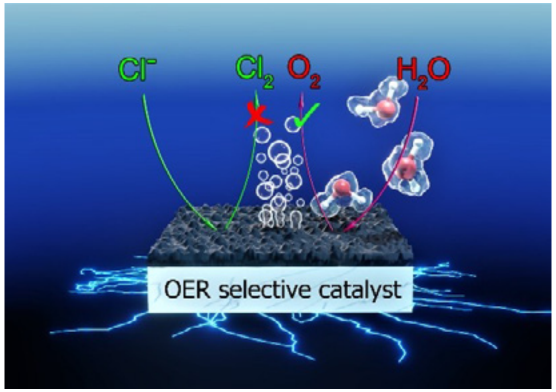
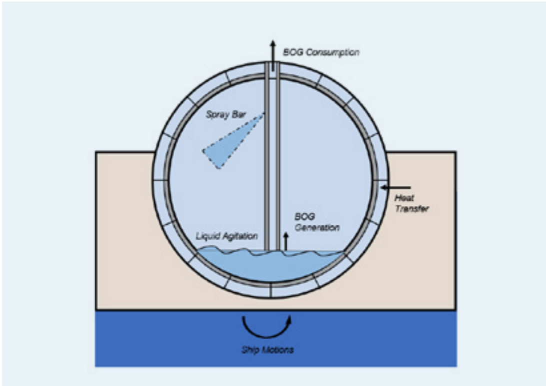
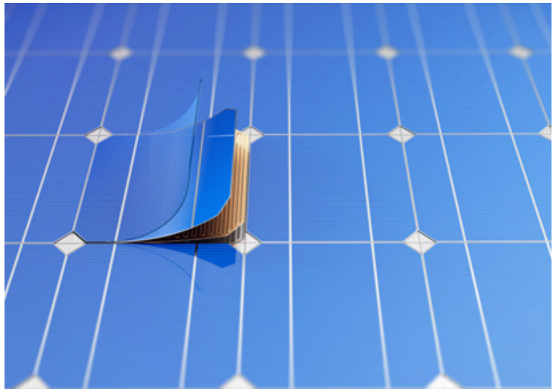
A/Prof. Gerry Nagtzaam	Dr Marc Senders
Prof. Wray Buntine	Michael Lawrence
Alejandra Mendoza Alcantara	Alexandra Convery
Dr Caitlin Doogan	
Dr Abby Wild	
Jingtian Wang	
Nicholas Yang	

NEW ENERGY TECHNOLOGIES







EFFICIENT ELECTRODES

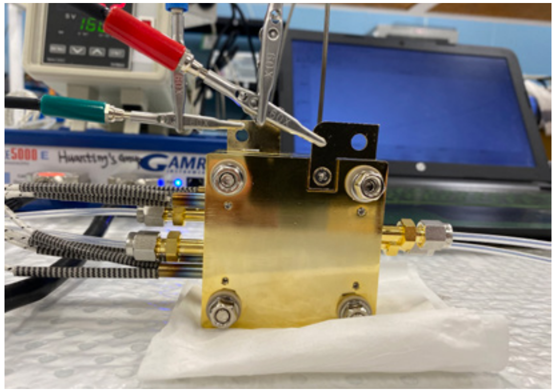
- Stage 2 of the seawater electrolysis program.
- Project is designing an electrolyser capable of splitting purified sea water to H2 and O2, by development of electrocatalysts.
- Current works has demonstrated enhanced mass-activity of oxygen evolution catalysts by oxidatively induced etching (ACS Energy Lett. 2022, 7, 3910–3916). A new family of electrocatalysts operating with ~90% selectivity for the oxygen evolution reaction in simulated seawater has been developed.
- New electrolyser design for electrolysis of seawater without the use of expensive ion-selective membranes has been proposed.

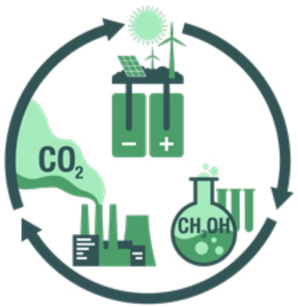
LIQUID H2 BOIL-OFF GAS MANAGEMENT

- Current liquid hydrogen storage tanks rely on complex double-shelled configurations with active cooling to minimise boil off.
- This project is assessing the feasibility of utilising para-ortho conversion for boil-off gas reduction through modelling and experimentation.

ULTRA-LOW-COST PHOTOVOLTAICS

- Re-imagining solar photovoltaic PV at a utility-scale to drive down the levelised cost of energy by maximising the energy density of shipped PV and reducing the deployment costs.
- This project is developing streamlined ultra-thin and low weight Si-PV, alongside novel deployment and solar tracking solutions to drive down the levelized cost of energy.
- A 10kW pilot plant has currently been developed and deployed as a proof of concept.





SOLID OXIDE ELECTROLYSIS

- Solid Oxide Electrolysis (SOEC) is an all-ceramic device, which operates at high temperature for applications such as hydrogen production via water splitting and carbon dioxide conversion into CO and other chemicals.
- Significant efforts have been made to develop SOEC technology and demonstrate SOEC systems from lab to pilot scale over the last decades.
- This project is prototyping next generation SOEC for water splitting and CO_2 conversion.

VIABLE PATHWAYS FOR GREEN METHANOL IN THE ENERGY TRANSITION

- Methanol has been identified as a key chemical industry feedstock and alternative fuel for decarbonization.
- There are many synthesis routes for methanol from biomass sources or captured CO_2, creating potential for small- and large-scale production in a variety of scenarios.
- This project's aim is to develop a comprehensive and adaptable sustainability assessment framework to determine the viability of green methanol production and use by case.

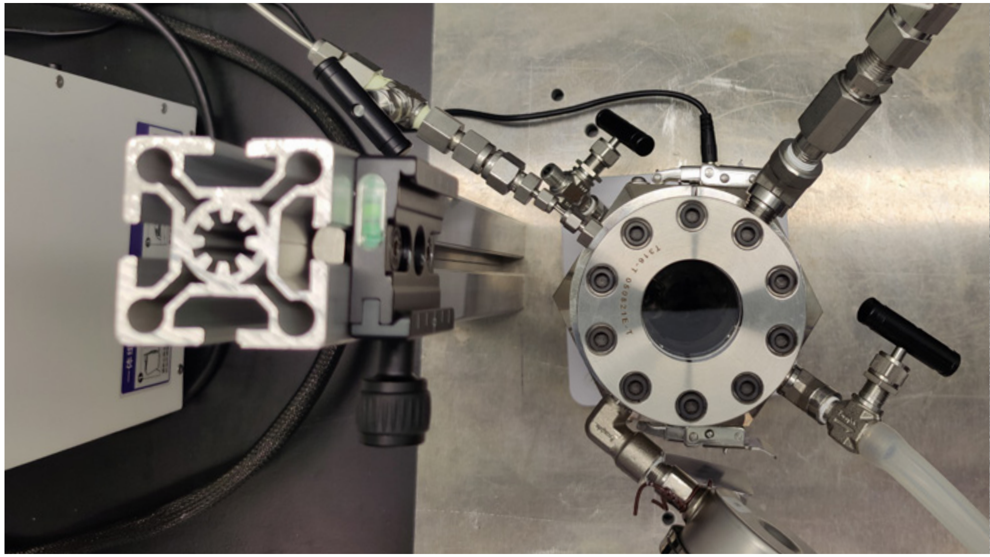
PROCESS INTEGRATION OF NET ZERO ENERGY, HYDROGEN AND AMMONIA PRODUCTION

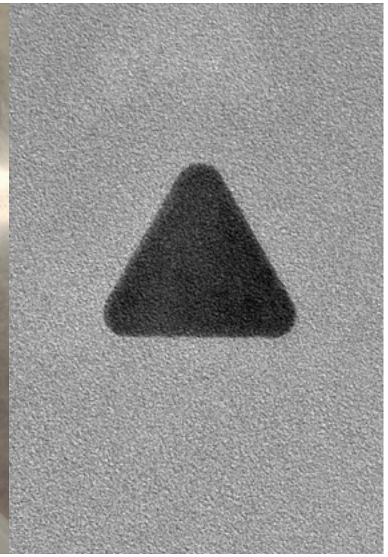
- Modelling stand-alone process for Net Zero cycle, hydrogen and ammonia production.
- Sensitivity analysis and optimisation in order to fully analyse the system's behaviour.
- Investigating different scenarios of integration and processes by energy and exergy analyses.

CARBON CAPTURE, CONVERSION AND UTILISATION

CO_2 CONVERSION BY PLASMONIC CATALYSTS

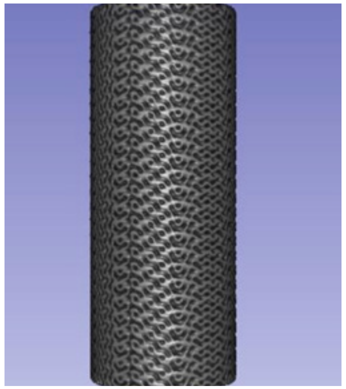
- Conventional catalysts for the conversion of CO_2 to value-added products require high reaction temperatures and pressures, prohibiting a cost-effective solution.
- This project is developing new multifunctional nanocatalysts that can efficiently and cost effectively convert CO_2 into value added products using plasmonics.
- Designed to be readily integrated with renewable energy, this approach will enable the production of chemicals under near ambient conditions and visible light excitation.

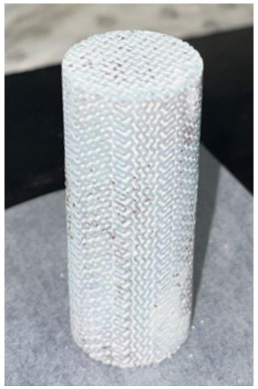


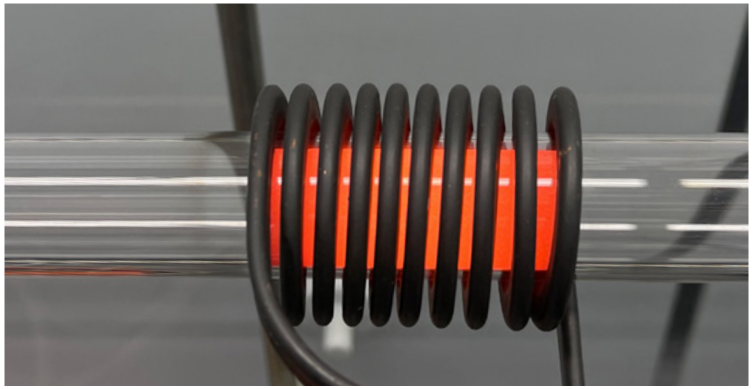


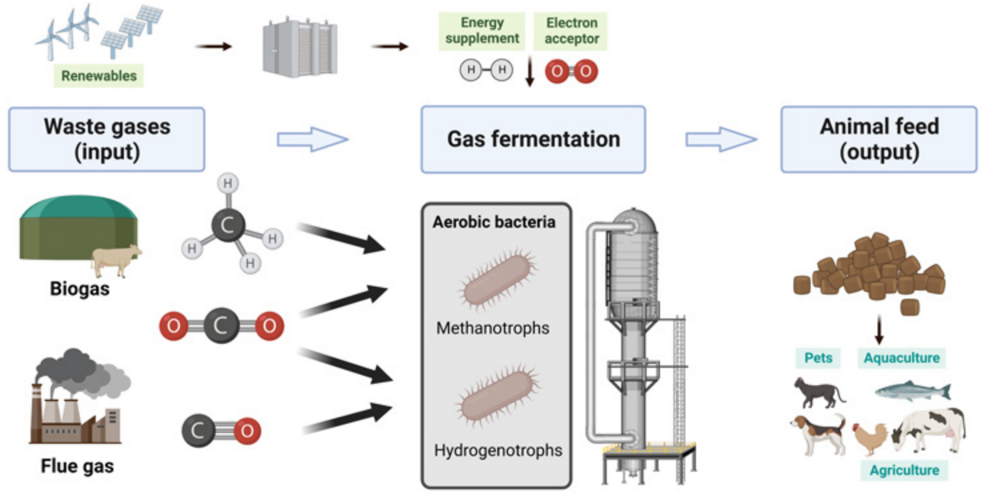
GAS PHASE CO_2 CONVERSION

- An attractive option for CO_2 utilisation into fuels and chemicals is the conversion of CO_2 into synthesis gas ($CO+H_2$) via dry or tri-reforming of methane.
- These reactions however are highly endothermic, have associated catalyst coking issues and hence pose challenges for large scale applications.
- This work is using novel heating technologies to reduce energy requirements, while also incorporating state of the art catalysts for improved efficiency.









CONVERSION OF WASTE GASES INTO SUSTAINABLE FEEDS

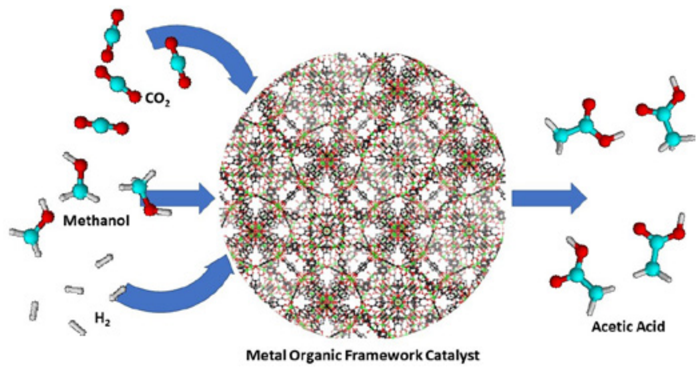
- Synthetic biology is turning biology into the manufacturing paradigm of the future.
- This project uses chemoautotrophic bacteria to efficiently convert waste gases into protein-rich biomass.
- By utilisation of waste gases, including CO_2, CH_4, and CO, it provides a novel biological process to convert waste gas emissions into sustainable feeds.

DIRECT AIR CAPTURE OF CO_2

- Direct air capture (DAC) of CO_2 has been identified as a prospective pathway to mitigate the effects of global warming.
- The aim of this development is to design an energy and cost-efficient DAC technology that is economically scalable and will cost less than $150 per tonne of CO_2 captured.
- Current work has developed prototypes for testing adsorbents, contactors, and process conditions for both feed and regeneration conditions.
- The final solution will be scalable to 1000t/day either through sizing or modularity.

ACETIC ACID PRODUCTION BY CO_2 CONVERSION

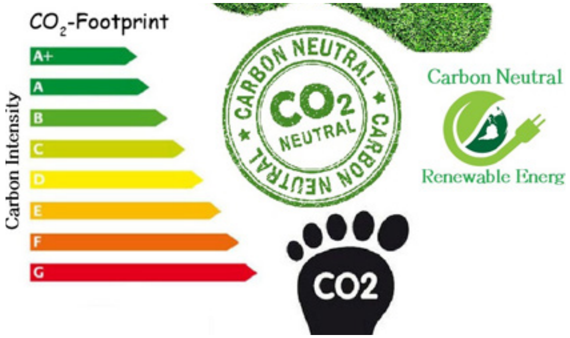
- Acetic acid is produced with high conversion and selectivity over novel metal organic framework catalysts.
- Hydrocarbonylation reaction of methanol with CO_2 and hydrogen as the reactants.



ENERGY LEADERSHIP

GREEN ENERGY IN THE GLOBAL STAGE – TECHNICAL AND ECONOMIC POTENTIALS OF HYDROGEN PRODUCTION

- A multi-disciplinary and multi-stakeholder approach that examined inter-related thematic dimensions that impact the future green hydrogen market
- The project developed insights into policies, initiatives and market development for green hydrogen, with reference to specific global regions
- For those specific global regions investigated, regional characteristics were also investigated using geospatial approaches.

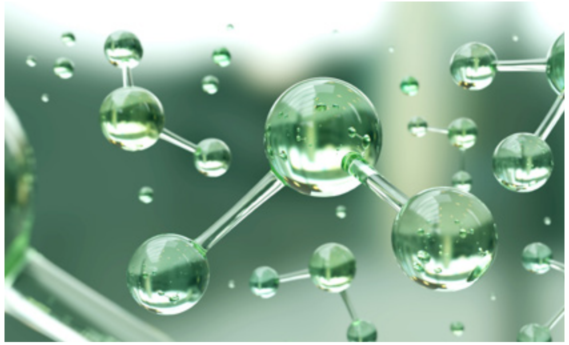


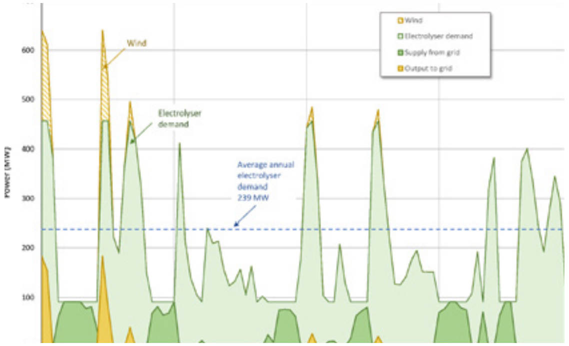
ANALYSING THE IMPACT OF CARBON LABELLING AND CARBON NEUTRAL CERTIFICATES ON CONSUMER BEHAVIOUR

- Focussed on carbon labelling schemes in the Australia energy sector
- Explores how market mechanisms, socio-economic factors and policy tools can influence sustainable consumer choices

EVALUATING AUSTRALIA'S COMMODITY EXPORT PATHWAYS IN THE GREEN HYDROGEN ECONOMY

- This project investigates the potential for international trade in green hydrogen and related green commodities.
- This research aims to aid Australia in its goals to become a key exporter of these new commodities, helping it to address the challenges associated with the transition to a net-zero economy.
- This will involve the development of a novel shipping cost toolbox, "Xporter", capable of computing optimal shipping routes for green commodities from any origin port to any destination port around the world.





SHAPING AUSTRALIA'S HYDROGEN MARKET

- This project investigated the development of hydrogen markets in Australia
- More specifically, focusing on the forces influencing hydrogen energy adoption for business customers and the potential role of hydrogen hubs in the energy transition.

LIFE CYCLE ANALYSIS FOR ENERGY PATHWAY SCENARIOS

- Using a prior developed tool, this project extended current work and conducted a detailed life cycle analysis for energy export scenarios for two locations in Australia.
- In this phase the model was extended to incorporate information for carbon intensity of grid-based electricity under a range of scenarios as an important requirement for certification of hydrogen production for grid-connected projects.

2022 PERSONNEL

WOODSIDE MONASH PARTNERSHIP – LEADERSHIP

NAME	INSTITUTION	ROLE	INITIATIVES	
Professor Maria Garcia de la Banda	Monash University	Monash FutureLab Co-Chair, Information Technology	Monash FutureLab	●
Professor Chris Hutchinson	Monash University	Monash FutureLab Co-Chair, Engineering	Monash FutureLab	●
Dr Erin Brodie	Monash University	Research and Innovation Manager	Monash FutureLab	●
Dr Sebastian Thomas	Monash University	Materials Durability Theme Leader	Monash FutureLab	●
Dr Lee Djumas	Woodside Energy	AM Subject Matter Expert	Monash FutureLab	●
Michael Brameld	Woodside Energy	Principal Materials Engineer	Monash FutureLab	●
Professor Paul Webley	Monash University	Energy Partnership Director	Energy Partnership	●
Dr Matt Nussio	Monash University	Energy Partnership Associate Director	Energy Partnership	●
Jason Hill	Woodside Energy	Woodside Monash Partnership Manager	Energy Partnership & Monash FutureLab	● ●
Voula Terzoudi	Woodside Energy	Head of Partnerships (Woodside Energy)	Energy Partnership & Monash FutureLab	● ●
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A/Prof Akshat Tanksale	Monash University	Carbon Theme Leader	Energy Partnership	●
Dr Tom Hughes	Monash University	New Energy Theme Leader	Energy Partnership	●
Professor Fang Lee Cooke	Monash University	Energy Leadership Theme Leader	Energy Partnership	●
Professor Murali Sastry	Monash University	Global Partnerships Theme Leader	Energy Partnership	●
Justine Sik	Monash University	Senior Project Officer	Energy Partnership	●
Evangeline Leong	Monash University	Operations Assistant	Energy Partnership	●

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Professor Mike Ryan	Monash University	Pro Vice-Chancellor (Research)
Professor Chris Davies	Monash University	Interim Dean, Faculty of Engineering
Tony Almond	Woodside Energy	Vice President, Technology
Jason Crusan	Woodside Energy	Vice President, New Energy Solutions
Professor Jordan Nash	Monash University	Dean, Faculty of Science
Professor Simon Wilkie	Monash University	Dean, Faculty of Business and Economics
Professor Ann Nicholson	Monash University	Dean, Faculty of Information Technology
Neil Kavanagh	Woodside Energy	Chief Scientist
Dani Howden	Monash University	Senior Director, Development

WOODSIDE MONASH PARTNERSHIP LEADERSHIP

(Back row, L to R):
Michael Brameld
Dr. Lee Djumas
Dr. Matthew Nussio
Dr. Erin Brodie
Dr. Sebastian Thomas

Front row, L to R):
Jason Hill
Professor Maria Garcia de la Banda
Professor Paul Webley
Voula Terzoudi
Professor Christopher Hutchinson

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MONASH FUTURELAB	CREATING THE AM PART PATHWAY	Prof Christopher Hutchinson	Professor and Co-chair
ADDITIVE MANUFACTURING	FAST TURNAROUND AM POLYMER PARTS	Dr Sebastian Thomas	Senior Lecturer
MATERIALS FOR NEW ENERGY	AM ALLOY DEVELOPMENT FOR NEW ENERGY APPLICATIONS	Dr Lee Djumas	AM Subject Matter Expert
ENERGY PARTNERSHIP COLLABORATIONS	EFFECTS OF ANOMALIES ON ELECTROCHEMICAL AND MECHANICAL PERFORMANCE	Dr Erin Brodie	FutureLab Research Manager
	BROADENING AM TO LARGE PARTS AND PART REPAIR	Dr Victor Cruz de Faria	Research Fellow
		Dr Darren Cram	Research Affiliate
		Brett Williams	Technician and Machinist
		Catherine Lee	PhD Student
		Georgia Hunter	PhD Student
		James Bott	PhD Student
		Marc Peters	PhD Student
		Shengning Meng	PhD Student
		Cristian Costa	PhD Student
		Jingjie Huang	PhD Student
		Matthew Hamod	Undergraduate Intern
		Sophia Maisey	Undergraduate Intern
		Matthew Issko	Undergraduate Intern
		Elisabeth Wong Hansen	Undergraduate Intern
		Austin Hollingsworth	Undergraduate Intern
		Katrina Bellesis	Final Year Project Student
		Farrel Christian	Final Year Project Student
		Kit Kirby	Final Year Project Student
		Riley Anstee	Summer Research Student
DATA SCIENCE	H2 NETWORK OPTIMISATION CHALLENGE	Prof Maria Garcia de la Banda	Professor and Co-chair
	MACHINE LEARNING FOR CORROSION DETECTION IN METAL	Prof Jianfei Cai	Professor
	PIPE ROUTING	A/Prof Dr Michael Wybrow	Senior Lecturer
		Dr Ilankaikone Senthooran	Research Fellow
		Dr Tobias Czauderna	Research Fellow
		Dr Frits de Nijs	Research Fellow
		Matthias Klapperstueck	Research Fellow
		Thomas Nobes	PhD Student
		Renuka Sharma	PhD Student
		Peter Gill	Summer Research Student
		Hai Ho	Summer Research Student
DECOMMISSIONING	SEPARATION OF UMBILICAL & FLEXIBLE FLOWLINES INTO USABLE MATERIALS	Prof Sankar Batthacharya	Professor
	PETROCHEMICAL PROCESSING OF FLEXIBLE FLOWLINE POLYMERS	Dr Victor Chang	A/Professor
		Dr Chao Chen	A/Professor
		Dr Chunyang Chen	Senior Lecturer
		Dr Jenny Zhou	Lecturer
		Dr Yunlong Tang	Lecturer
		Dr Mahmud Kibria	Research Fellow
		Ben Thomas	PhD Student
		Xingdong Wang	PhD Student
		Ben Liu	PhD Student
		Cornellio Setianto	Undergraduate Intern

INITIATIVE / THEME	PROJECT	RESEARCHERS	ROLE
ENERGY PARTNERSHIP **NEW ENERGY TECHNOLOGIES**	**EFFICIENT ELECTRODES FOR SEA WATER ELECTROLYSIS**	Dr Alexandr N Simonov	Primary Chief Investigator
		Prof Douglas R MacFarlane	Chief Investigator
		Dr Roy Dinh	Postdoctoral Fellow
		Anmol Vaidya	Masters Student
	LH2 BOIL-OFF GAS MANAGEMENT	Dr Tom Hughes	Primary Chief Investigator
		Prof Paul Webley	Chief Investigator
		Liam Turner	PhD Student
		James Wang	PhD Student
		Nicholas Boal	FYP Student
		Nirvan Ganapathy	FYP Student
		Nathaniel Grieef-Dickerson	FYP Student
	ULTRA-LOW-COST PV	Prof Jacek Jasieniak	Primary Chief Investigator
		A/Prof Chao Chen	Primary Chief Investigator - Robotics
		Dr. Matthieu Gresil	Chief Investigator
		A/Prof Amin Haidarpoiur	Chief Investigator
		Dr Reza Razzaghi	Chief Investigator
		Dr Stuart Walsh	Chief Investigator
		Jose Lobo Del Canto	Research Officer
		Alexandar May	Research Officer
		Jefferson Lam	PhD Student
		Dr Gaveshana Sepalage	Postdoctoral Fellow
		Charles Troeung	Research Assistant
		Xinyu Cao	Masters Student
		Yuan Liu	Masters Student
		Zhengyu Chu	Masters Student
		Tianyu Xi	Masters Student
		Xiaoyu Hong	Masters Student
		Hanqi Hu	Masters Student
		Henry Jiang	FYP Student
		Emily Qiao	FYP Student
		Mitchell Mibus	FYP Student
		Jack Braddick	FYP Student
		Tianyu Xi	FYP Student
		Samuel Warren-Smith	FYP Student
		India Wentworth	FYP Student
		April Synhur	FYP Student
		Anmolpreet Singh	FYP Student
	SOLID OXIDE ELECTROLYSIS	Prof Huanting Wang	Primary Chief Investigator
		Prof Paul Webley	Chief Investigator
		Prof Jacek Jasieniak	Chief Investigator
		Dr Dehua Dong	Postdoctoral Fellow
		Kaiqing He	PhD Student
		Kevin Ung	PhD Student
	VIABLE PATHWAYS FOR GREEN METHANOL IN THE ENERGY TRANSITION	Prof. Paul Webley	Primary Chief Investigator
		Prof Damon Honnery	Chief Investigator
		Miriam Blaine	PhD Student
	PROCESS INTEGRATION OF NET ZERO ENERGY, HYDROGEN, AND AMMONIA, PRODUCTION	Dr Tom Hughes	Primary Chief Investigator
		Prof. Paul Webley	Chief Investigator
		Javad Jeddizahed	PhD Student

ENERGY PARTNERSHIP

CARBON CAPTURE, CONVERSION AND UTILISATION

INITIATIVE / THEME	PROJECT	RESEARCHERS	ROLE
Carbon Capture, Conversion and Utilisation	GAS PHASE CO_2 CONVERSION	A/Prof Akshat Tanksale	Primary Chief Investigator
		Prof Matthew Hill	Chief Investigator
		Prof Kiyonori Suzuki	Chief Investigator
		Dr Lee Djumas	Chief Investigator
		Dr Munir Sadiq	Postdoctoral Fellow
		Hamza Asmat	PhD Student
		Ponnamperumage Anne Shalini Maneesha Fernando	FYP Student
		M Hanif Abdurrahim Ar Rafai	FYP Student
	CO_2 CONVERSION BY PLASMONIC CATALYSTS	Prof Murali Sastry	Primary Chief Investigator
		A/Prof Akshat Tanksale	Chief Investigator
		A/Prof Philip Nakashima	Chief Investigator
		A/Professor Laure Bourgeois	Chief Investigator
		Tuncay Alan	Chief Investigator
		Dr. Sanje Mahasivam	Postdoctoral Fellow
		Dr Waqar Ahmad	Postdoctoral Fellow
		Garv Bhardwaj	PhD Student
		Fergus McLaren	PhD Student
	DIRECT AIR CAPTURE OF CO_2	Prof Paul Webley	Primary Chief Investigator
		Prof Matthew Hill	Chief Investigator
		A/Prof Akshat Tanksale	Chief Investigator
		Dr Joanne Tanner	Chief Investigator
		Dr Masood Sheikh Alivand	Postdoctoral Fellow
		Dr Munir Sadiq	Postdoctoral Fellow
		Jose Arredondo Arcos	Analyst
		Romalya Ranasingh	PhD Student
		Maksis Darzins	Intern
		Joel Wong	Intern
		Umma Habiba	Postdoctoral Fellow
		Harry Blackburn	FYP Student
		Jonathan Kossasih	FYP Student
		Payton Seeto	FYP Student
		Huilin Huang	FYP Student
		Tyler Swann	Summer Research
		Joseph Ward	Summer Research
		Micah Ramsay	MITI
		Jeremy Ong	MITI
		Nick Sourlos	MBA Student
		Vanshika Mehra	MBA Student
		Amandeep Singh	MBA Student
		Nithurshan Nadarajah	MBA Student
	ACETIC ACID PRODUCTION BY CO_2 CONVERSION	A/Prof Akshat Tanksale	Primary Chief Investigator
		Prof Alan Chaffee	Chief Investigator
		Rajan Lakshman	PhD Student
	CONVERSION OF WASTE GASES INTO SUSTAINABLE FEEDS	A/Prof Chris Greening	Primary Chief Investigator
		A/Prof Esteban Marcellin	Primary Chief Investigator (UQ)
		A/Prof Akshat Tanksale	Chief Investigator
		Dr Surbhi Jain	Postdoctoral Fellow
		Dr James Heffernan	Postdoctoral Fellow (UQ)
		Evangeline Leong	FYP Student

INITIATIVE / THEME	PROJECT	RESEARCHERS	ROLE
ENERGY PARTNERSHIP **ENERGY LEADERSHIP**	**LIFE CYCLE ANALYSIS FOR ENERGY PATHWAY SCENARIOS**	Dr Roger Dargaville	Primary Chief Investigator
		Prof Damon Honnery	Chief Investigator
		A/Prof Andrew Hoadley	Chief Investigator
		Dr Graham Palmer	Postdoctoral Fellow
		Dr Changlong Wang	Postdoctoral Fellow
	ANALYSING THE IMPACT OF CARBON LABELLING AND CARBON NEUTRAL CERTIFICATES ON CONSUMER BEHAVIOUR	Prof Srinivas Sridharan	Primary Chief Investigator
		Prof Fang Lee Cooke	Chief Investigator
		Stephan Modest	PhD Student
	GREEN ENERGY IN THE GLOBAL STAGE - TECHNICAL AND ECONOMIC POTENTIALS OF HYDROGEN PRODUCTION	Prof Fang Lee Cooke	Primary Chief Investigator
		Dr Xuan Zhu	Primary Chief Investigator
		Stephan Modest	Research Assistant
		Lynn Wu	Research Assistant
		Warsini Handayani	PhD Student
	EVALUATING AUSTRALIA'S COMMODITY EXPORT OPPORTUNITY IN THE GREEN HYDROGEN ECONOMY	Dr Stuart Walsh	Primary Supervisor
		Dr Gordon Leslie	Chief Investigator
		Dr Changlong Wang	Chief Investigator
		Israel Lutalo	PhD Student
	SHAPING HYDROGEN MARKET	Prof Sudha Mani	Primary Chief Investigator
		Prof Sharon Purchase	Primary Chief Investigator (UWA)
		Daniel Schepis	Chief Investigator (UWA)
		Stephan Modest	Research Assistant
		Isaac Lee	Research Assistant (UWA)

Energy Partnership visit to Great Wrap – Tullamarine Factory;
L-R: Evangeline Leong, Professor Paul Webley, Jordy Kay, Dr Martin Markotsis, Associate Professor Akshat Tanksale, Dr. Matt Nussio

Energy Partnership and Monash Carbon Capture and Conversion visit to the CO2CRC's Otway International Test Centre

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A partnership between:

The information in this brochure was correct at the time of publication.
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Produced by UMAC, Monash University. 23-AS016 April 2023.
CRICOS provider: Monash University 00008C.