CONTENTS

FOREWORD FROM PROFESSOR KEN SLOAN 1
INTRODUCTION
   MONASH FUTURELAB 2
   ENERGY PARTNERSHIP 3
HIGHLIGHTS AND EXTERNAL ENGAGEMENT
   MONASH FUTURELAB 4
   ENERGY PARTNERSHIP 6
MONASH FUTURELAB
   EVOLVED VISION 8
   PROJECTS 9
ENERGY PARTNERSHIP
   STRATEGIC RESEARCH THEMES 15
   PROJECTS 16
KEY PERSONNEL 24
As a philanthropic partnership, 2020 also landmarks a 5-year milestone for the Woodside FutureLab at Monash, and together with the leadership appointments of both the Woodside FutureLab and Woodside Monash Energy Partnership, I look forward to the future developments of these strategic partnerships.

The year 2020 also saw a transition in our leadership for both the Woodside FutureLab at Monash and the Woodside Monash Energy Partnership. The leadership of the Monash FutureLab officially evolved into a Co-Chair form; Professor Maria Garcia de La Banda and Professor Christopher Hutchinson shifting from their acting roles to continue driving the leadership and innovation of the Monash FutureLab and its positive impact on Woodside operations. We also welcomed the appointment of Professor Paul Webley to the role of Energy Partnership Director for the Woodside Monash Energy Partnership. With over 15 years of industry and academic experience in the development and management of clean energy technologies, Professor Paul Webley’s appointment was a significant milestone to the Woodside Monash Energy Partnership. I would also like to acknowledge and thank Professor Damon Honnery and Professor Jacek Jasieniak for their exceptional contributions in setting up and leading the development of the Woodside Monash Energy Partnership since its inception in 2019.

As a trusted partnership, the collaboration and spirit between Woodside and Monash is a platform that continues to accelerate breakthroughs in next-generation technologies, energy efficiency, cleaner energy, and sustainable industrialisation.

2020 also landmarks a 5-year milestone for the Woodside FutureLab at Monash and as a renewed philanthropic partnership that strengthens our long-term strategic relationship, together with the recent leadership appointments, I look forward to our future developments and shared impact for this strategic partnership.

In 2020, the Woodside Building for Technology and Design was also completed and reflecting Monash’s commitment to achieving Net Zero Emissions by 2030, the building also achieved rigorous Passive House certification. The application of Passive House building standards and the design of the building as a living laboratory is redefining best practices in building design, teaching, and learning practices. Located in the Monash Technology Precinct, and by Woodside’s generous philanthropic support, I’m pleased to share the Woodside Building for Technology and Design is the largest Passive House project in the Southern Hemisphere.

Technology and innovation are essential to Woodside’s long-term sustainability, providing an ever growing opportunity landscape for Woodside and Monash to work together and with partners to accelerate our progress. It is through this Partnership we continue to accelerate the energy transition through cutting-edge research to creating job-ready graduates, and endure the grand challenges of the energy sector and ultimately society. I am pleased to share this annual review, our joint developments, and the successful outcomes of 2020.

Professor Ken Sloan
Deputy Vice-Chancellor and Senior Vice-President (Enterprise and Governance)
2020 was a year unlike any other for all of us. We recognise the incredible challenges that the year presented us, and we are proud of the way the Woodside FutureLab at Monash was able to respond and adapt. We took the opportunity to realign our ambitions and our vision for the future while continuing to deliver on a range of key projects. The end of 2020 saw the official completion of the initial 5-year philanthropic agreement between Monash and Woodside, providing us with the chance to reflect on the numerous successes of the previous 5 years, as well as on the many opportunities for growth and improvement in the next 5 years.

An important event in last year’s journey for the Monash FutureLab was the appointment of Professor Christopher Hutchinson and Professor Maria Garcia de la Banda as Co-Chairs, from their previous acting roles, and with it, the exciting task of setting the path for the next 5 years. Chris and Maria have been involved in the Monash FutureLab since its inception and have been central to the development of the culture and spirit of the program. This Co-Chair arrangement signals our aspirations to coherently integrate the areas of Materials (and Engineering more broadly) with those of Data Science (and IT more broadly) to drive innovative and collaborative projects that are more than the sum of their parts. We are proud to present this vision further within this report.

We feel that it is timely to recognise the important contributions over the last 5 years of the Monash FutureLab team at large. This especially includes Dr Sebastian Thomas, who has been integral in delivering some of the most important projects to Woodside, including the use of STOPAQ barrier coatings to stainless steel components and piping and the development of a probe for use in Corrosion Under Insulation inspection and maintenance. As such, we are excited to appoint Dr Thomas as a Theme Lead in Materials Durability under the Monash FutureLab banner.

While the challenges of 2020 persisted, we ensured that momentum on key projects was maintained as we hope will be reflected in this report. We are also excited to once again be exploring new project opportunities with Woodside, as 2021 begins in earnest.

As always, we are reminded of how special this partnership with Woodside is, the commitment, the trust, the individual relationships, the truly fantastic work that we get to do. The in-person contact with our Woodside collaborators, and indeed friends, was sorely missed this year.

The opportunity to freely share new ideas and projects, to delve deep into the technical details, and the chance to provide insight into current challenges are all things we eagerly look forward to in 2021.

Professor Christopher Hutchinson
Monash FutureLab Co-Chair, Engineering

Professor Maria Garcia de la Banda
Monash FutureLab Co-Chair, Information Technology

Dr Lee Djumas
Research and Innovation Manager

Jason Hill
Monash FutureLab Manager
Now in its second year, the Woodside Monash Energy Partnership has started gaining pace in both its leadership and research program. As a major research partnership between Monash University and Woodside Energy, the Partnership continues to progress energy solutions for a lower carbon future. In 2020, Professor Paul Webley joined as Professor and Director of the Partnership. With industrial experience in the development of clean energy technologies, Paul’s leadership appointment came at a crucial point of the Partnership with several projects in 2020 shifting from feasibility to technology development.

The Partnership also established the full leadership committee, appointing Professor Fang Lee Cooke as Energy Leadership Theme Leader and Professor Jacek Jasieniak as New Energy Theme Leader. Working alongside Energy Leadership Theme Leader counterpart at Woodside, Peter Metcalfe, Fang and Peter continue to drive opportunities for policy development to accelerate the energy transition. Previously in the capacity of interim Co-Director of the Partnership, Jacek continues his support and leadership for the Partnership now focussing on technology development of new energy technologies at scale. Together with Dr Jitendra Joshi, New Energy and Carbon Theme Leader at Woodside, the new energy theme also commissioned the next stage of the seawater electrolysis project as an achievable pathway to large-scale green hydrogen production.

While the implementation of green hydrogen is an important focus of the Partnership, we are also taking a regenerative and circular approach to the energy transition. In the carbon theme, we have created pathways for emissions to be reused or recycled. This is in strong alignment with the recent Technology Investment Roadmap announced by the Federal Government that emphasises the role of Carbon Capture, Utilisation, and Storage. There is an urgent need to build capacity for a circular carbon economy in Australia and this is a core focus of the Partnership.

Policy and leadership are also critical, where the energy leadership theme is investigating opportunities for carbon labelling as an effective policy tool to drive behaviours. As a landmark partnership between Woodside Energy and Monash University, the Partnership is accelerating the development of new solutions to shared global energy challenges. Collaboration across industrial sectors is also critical, where a number of programs with broader industry partners are already in development. As a partnership founded on bringing together the best minds to bear on any business or technical problem, we welcome opportunities to join forces on this energy transition and are excited to share our achievements to date.

Professor Paul Webley
Energy Partnership Director

Andrea Galt
New Energy Partnership Program Director

Dr Matt Nussio
Energy Partnership Senior Manager

Justine Sik
Senior Project Officer
This year was one of agility and evolution for the Monash FutureLab with efforts to advance and grow from the success of the past 5 years. Stability was maintained through the continuation of major projects and this contributed to a productive year which is reflected in the following highlights.

- Building upon the relationships developed within the Monash FutureLab over the past 5 years, the leadership model has evolved into Co-Chair form to benefit from the increasing overlap, collaboration and synergies between Engineering and IT.
- Dr Sebastian Thomas has been appointed Materials Durability theme Lead, recognising his major contributions to the partnership in leading projects which led to field implementation of the CUI probe, STOPAQ and Aluminium scaffolding.
- The full-time Woodside presence at Monash (initially Michael Ford and then Jason Hill) has led to much stronger ties with multiple technical leads including Darren Shanahan, Michael Brameld and Andrew Lockwood.
- The Additive Manufacturing (AM) effort within Woodside has been refocussed with the first installation-ready pressure containing component and the rationalisation of AM materials to the 1-2 most useful ones for Woodside within the framework of the AM Roadmap.
- Exciting new Data Science projects have been established (smart inventory analysis and corrosion detection), while others have been completed (seismic data denoising).
- The Plant Layout system is now able to recover from user input errors, explain where the error is and suggest possible ways to correct it.
- A strong pipeline of new students at all levels has been recruited over Semester 2 2020 into 2021.
- Support has been provided to the Woodside Monash Energy Partnership to a) expand and build upon the Woodside Monash relationship, b) work collaboratively across a number of projects and c) leverage the full extent of capabilities across the two endeavours.
- The Wind Tunnel being awarded a significant grant, with support from Woodside and Chevron, to model cyclone behaviour in relation to key Woodside assets in the North West Shelf.
EXTERNAL ENGAGEMENT

We have been extremely proud of our efforts over the last 5 years to engage the broader community and have impact beyond direct R&D outcomes. During 2020 these outreach efforts were even more important and also even more challenging than before. The following provides a short snapshot of some of these efforts.

- In response to COVID, the Monash FutureLab supported research conducted at Monash Health to test the efficacy of adapted snorkel masks using 3D printing. We developed a safe procedure to 3D print and deploy the masks for clinical trials.
- Continued work with around a dozen of Monash’s excellent student teams including: Monash Motorsport, Monash Young MedTech Innovators, Monash Energy Club, and Materials Student Society, amongst many others.
- Supported Monash Industry Team Initiative working on improved cross-laminated timber.
- Partnered and worked with several Monash start-up companies, including Additive Assurance Varden and TuCann Medical.
- Dr Lee Djumas delivered a talk on the Monash FutureLab’s work in Additive Manufacturing to the Monash Precinct Showcase Event on Digital Aspects of Additive Manufacturing.
- Maria Garcia de la Banda presented the partnership to the leadership of several companies, including CSL, DST and Agilent, which are seeking to establish a stronger partnership with Monash and see the Woodside Monash partnership as a remarkably successful model.
2020 HIGHLIGHTS

Officially launched in July 2019, the Energy Partnership reached its one-year milestone in 2020. Although it was a year of many unforeseen challenges, the Energy Partnership continued to drive impact toward a lower carbon future. The Partnership expanded in its leadership and research programs, while continuing to engage with national and global stakeholders of the energy transition. 2020 also saw the completion of the Woodside Building for Technology and Design, the home of the Woodside Monash Energy Partnership, and one of the most efficient and innovative teaching buildings of its kind.

The following highlights are presented:

LEADERSHIP

- After an extensive global search, the Partnership appointed Professor Paul Webley as Director of the Woodside Monash Energy Partnership.
- Appointment of Professor Jacek Jasieniak as New Energy Theme Leader and Professor Fang Lee Cooke as Energy Leadership Theme Leader.
- Dr Matt Nussio was appointed as Senior Manager and Justine Sik as Senior Project Officer to support strategic operations of the Partnership.

DECARBONISATION SPRINT

- Hosted the Energy Partnership’s first Decarbonisation Sprint.
- Over 60 people from 15 organisations participated.
- Key challenges and problems statements for decarbonisation were developed.
- Concepts for methods and approaches to feasibly transform carbon dioxide to long-lived carbon products were presented to judging panel.
- Leading concepts were further investigated and prototyped through a 12-week program supported by support of the Monash Industry Team Initiative.

STRATEGIC RESEARCH THEMES

- Across each of the three strategic research themes, several projects achieved Stage 1 completion.
- Next stage developments also commenced, including a major research program in saltwater electrolysis and electrode design, next stage planning in liquid hydrogen storage and the advancement of a tool for environmental impact and energy assessment.

WOODSIDE MONASH ENERGY PARTNERSHIP WEBINAR SERIES

- Supported by the Monash Energy Institute, a 4-part webinar series for the Woodside Monash Energy Partnership was facilitated.
- The webinar series hosted representatives from industry, academia, and national and international stakeholders of the global energy transition.
- Together, critical issues, challenges and opportunities of the energy transition were discussed, bringing together perspectives from technology, large scale deployment, environmental factors, policy, and the future workforce.
- Over the webinar series, 370 representatives joined from industry, academia and government.
WEBINARS

Attendees joined from industry, government and academia

over 370 attendees
global reach to over 10 countries

ENERGY PARTNERSHIP HOSTS

Professor Paul Webley
Energy Partnership Director
Monash University

Professor Jacek Jasieniak
New Energy Theme Leader
Monash University

Professor Fang Lee Cooke
Energy Leadership Theme Leader
Monash University

Associate Professor Akshat Tanksale
Carbon Theme Leader
Monash University

ENERGY PARTNERSHIP HOSTS

Jason Crusan
Vice President of Technology
Woodside Energy

Miranda Taylor
Chief Executive Officer
National Energy Resources Australia

Andrea Galt
New Energy Partnership Program Director
Woodside Energy

Professor Elizabeth Croft
Dean, Faculty of Engineering
Monash University

Dr Jitendra Joshi
Principal Scientist
New Energy and Carbon Theme Leader
Woodside Energy

Professor Jennifer Wilcox
Presidential Distinguished Professor
University of Pennsylvania

A/Prof Victoria Haritos
Department of Chemical Engineering
Monash University

Dr Ashley Roberts
Energy Transformation Engineer
Woodside Energy

Dr Graham Palmer
Department of Mechanical and Aerospace Engineering
Monash University

Dr Stuart Walsh
Department of Civil Engineering
Monash University

Dr Emma Aisbett
Associate Director, ANU Grand Challenge – Zero-Carbon Energy for the Asia Pacific
Australian National University

Peter Metcalfe
General Manager
Climate Engagement
Monash University

Dr Graham Palmer
Department of Mechanical and Aerospace Engineering
Monash University

Rob Kelly
Industry Lead
ClimateWorks Australia

ENERGY LEADERSHIP AND AUSTRALIA’S ENERGY TRANSITION

TRANSITIONING TO A LOWER CARBON FUTURE

LARGE-SCALE GREEN HYDROGEN PRODUCTION IN AUSTRALIA

CARBON REUSE AND TRANSFORMING EMISSIONS – CO2 TO PRODUCTS

ENERGY PARTNERSHIP

ENERGY PARTNERSHIP HOSTS
Our evolving vision of the Monash FutureLab is driven by the ever-growing need to collaborate across disciplines and are committed to exploring opportunities at the intersection of our three core themes of Additive Manufacturing, Materials Durability and Information Technology. This highlights our objectives to (a) focus on outcomes rather than on areas of expertise, and (b) develop a portfolio of short-, medium- and long-term projects capable of addressing current business issues, as well as supporting Woodside to proactively identify ways to address future challenges.

Five years ago, the Monash FutureLab was launched with the goal of developing the “Plant of The Future”. While we have made significant strides towards this goal, we believe it is important to make our focus more concrete and tangible, to better reflect the work that we undertake. With this in mind, we would like to propose as a new goal — “Towards a Smarter, Autonomous Plant” — which encapsulates our efforts to bring the very best of Monash expertise together into cross-disciplinary teams that can advance Woodside’s operations and create a Plant which is safer, more efficient, easier to manage, and ready for the next set of challenges it will face.
2020 saw the release of the AM Roadmap within Woodside, outlining the path forward for the company to utilise and deploy AM in a meaningful and systematic part of business as usual. The FutureLab at Monash played a key role in laying the foundations, working closely with our colleagues at Woodside to enable such a vision to take shape. We are very much looking forward to continuing our work to ensure that the targets laid out in the roadmap are met and realised.

A key tenet of the AM Roadmap is focusing on a single material that can address the challenges of all the various working conditions and environments that an Additively Manufactured component would face within Woodside operations. Such a material would be required to have an outstanding combination of properties to make it suitable. The Monash FutureLab, alongside partners in Woodside, Curtin University and University of Western Australia have begun to identify, test and develop such a material for use.

One of the initial components which were identified as suitable for AM was the monoflange which has been extensively redesigned for optimised pressure-containing service. It has been 3D printed by Monash and finished, fitted and tested by the OEM, such that it is now ready for service. While the monoflange project predates the current AM Roadmap, many of the lessons learnt along the way of this project have been integrated into the AM Roadmap.

Project members: Professor Christopher Hutchinson, Dr Sebastian Thomas, Dr Lee Djumas, Victor Cruz de Faria, Tim Murray, Catherine Li, Taylah Banham

Project members: Dr Lee Djumas, James Bott, Tim Murray, Victor Cruz de Faria
ADDITIVE MANUFACTURING

SUPPORTING QUALIFICATION: UNDERSTANDING THE EFFECTS OF DEFECTS

The use of AM within Woodside will rely on building trust and confidence that components which are 3D printed are safe to use. For AM, at this technology stage, completely removing all defects of any size from AM parts is extremely difficult. Additionally, there is a limited understanding of the effects of these, often small, defects. We have begun work on addressing this gap, to better understand which defects Woodside need to consider and as such, realise the most value from AM.

Project members: Professor Christopher Hutchinson, Dr Sebastian Thomas, Dr Lee Djumas, Victor Cruz de Faria, Thomas Whitehead, Shengning Meng, Isaac Frith

ADDITIVE MANUFACTURING

SUPPORTING QUALIFICATION: SURFACE EFFECTS ON CORROSION PROPERTIES

In addition to defects, the surface of as-printed AM components can often be slightly rougher than machined surfaces. While this can be easily addressed for external surfaces, internal surfaces, such as channels, are difficult to machine. As such, we need to understand what effect this surface roughness has, particularly on corrosion properties. While much work has been done on this in the context of stainless steels over the last 5 years, as we move forward with our ideal AM material, this work is being extended to include the new alloy(s).

Project members: Dr Sebastian Thomas, Dr Lee Djumas, Victor Cruz de Faria, Isaac Frith, Harry Nicholls
This project explored the potential of generative adversarial networks (GANs) for seismic noise attenuation, that is, detection and removal of random noise in a seismic shot record. The completed project has demonstrated the potential power of GANs to seismic processing, by using recent research such as the use of a Wasserstein loss and self-supervised learning, to build a model that was then applied to the 2D and 3D scenarios. While the accuracy obtained for the 2D scenario was high, the model did not perform as well for the 3D case, due to a lack of 3D data with which to train the model to decrease its parameter sensitivity. This can be remedied if more 3D data is produced.

Project members: Dr Xiaojun Chang, Dr Zhihui Li

Woodside purchases thousands of products each year and it is often unclear why some products can be received quickly while others can take a very long time indeed. Together with Woodside, we have started to explore 10 years of purchase order data that shows how long it takes to procure each item. While cleaning the data and preparing it for analysis proved to be more involved than expected, we have already started to understand some of the factors that explain lead time variations in the Woodside supply chain. The long-term aim is to accurately and automatically predict how long a particular purchase order will take, be able to explain the reasons behind the prediction and allow users to tailor the prediction to their particular case to increase its accuracy.

Project members: Dr John Betts, Anil Gurbuz
One of the most frustrating situations when waiting for a system like Plant Layout to produce an optimal solution, is to get a failure, that is, for the system to say there is no solution at all. This can be caused by a large variety of reasons, from too small plant dimensions and conflicting min/max separation distances, to equipment that is incorrectly required to be both on the ground and on top of some other equipment. Determining the exact cause is a very complex optimisation problem in its own right. In 2020 the Plant Layout software was modified to provide (a) a minimal set of reasons behind a failure and, importantly, and (b) how to modify the plant data inputs to recover from it.

Project members: Matthias Klapperstueck, Dr Tobias Czauderna, Dr Gleb Belov, Dr Ilankaikone Senthooran, Dr Michael Wybrow, Professor Maria Garcia de la Banda, Professor Mark Wallace

Woodside is increasing its use of Temporary Production Systems and optimising the layout of these systems brings several exciting new challenges, including a desire to use as many ‘standard’ sized (rather than bespoke) pipe segments as possible. To support this, the routing phase of the Plant Layout system was modified in 2020 to be able to route the pipes in such a way as to minimise the use of bespoke pipe segments. While this is a very exciting and significant achievement, even better results could be obtained if the equipment allocation phase of the plant layout system could be done at the same time as the pipe routing.

Project members: Matthias Klapperstueck, Dr Tobias Czauderna, Dr Gleb Belov, Dr Ilankaikone Senthooran, Dr Michael Wybrow, Professor Maria Garcia de la Banda, Professor Mark Wallace
After a successful training and initial trial of the corrosion under insulation (CUI) probe at the very beginning of 2020, which saw Sebastian Thomas and Qing Cao travel to Karratha, the CUI probe was implemented into an ongoing broader inspection trial program at KGP throughout 2020. At the conclusion of the field trial, the probe was shown to be effective in a number of locations, however further improvements to the reliability and stability of the probe were identified. These will be addressed and developed in Q2 2021 with further site testing planned for late 2021.

STOPAQ was approved for use as a barrier coating for stainless steel components and piping to mitigate pitting at the end of 2019. Since then, the team has focussed on finding other ways in which we could apply the important outcomes of this work to additional Woodside operations. Understanding that the key to the success of this approach is the suppression of oxygen and water to the pit site, work was conducted to find the transmission rates of STOPAQ and Humidor, another barrier coating. Utilising the latest corrosion models and this new data, accurate thresholds were identified to allow the use of other barrier coatings with known permeabilities, on Woodside assets. Patent applications for this procedure have been submitted.

The effort to detect corrosion from images using deep learning has been ongoing, with a renewed focus on utilising texture in images to support improved accuracy. This work has been benchmarked against the current state-of-the-art algorithms to identify if improvements can be made, such that the accuracy can reach a point where this approach can be applied more broadly in Woodside inspection procedures.
The Monash FutureLab has been eagerly collaborating and supporting the Energy Partnership over the last 18 months or so, in a myriad of ways. In particular, there have been a small number of projects where the Energy Partnership has been able to leverage the expertise and capabilities of the Monash FutureLab to drive projects forward. These include additively manufacturing monolith conversion vessels with complex internal structures for reforming methane via induction heating more efficiently, designing and 3D printing novel electrolyser for hydrogen production, and exploring the layout of a prototypic CO₂ plant using the existing LNG-focused plant layout software. We are excited to see these projects grow over the coming years.

Project members: Dr Lee Djumas, Victor Cruz de Faria, James Bott, Jacob Stiles, Matthias Klapperstueck, Dr Tobias Czauderna, Dr Gleb Belov, Dr Ilankaikone Senthooran, Dr Michael Wybrow

A partnership between Monash, Woodside and Chevron was successful in being awarded funding by the Australian Research Council to conduct the Project titled “Structural Reliability of Engineering Structures in Cyclonic Winds”. This project aims to address the challenge of predicting the impact of extreme cyclonic winds on complex engineering structures, such as Woodside’s offshore facilities. Work has commenced with the application of advanced computational and experimental techniques to develop new insight into turbulent flows at a sub-cyclone scale and understand how these flows produce aerodynamic loads on closely spaced cylindrical structures and elements. Initial results are expected during Q2 2021.

Project members: David Burton, Professor Mark Thompson, Professor Marc Parlange
STRATEGIC RESEARCH THEMES

To deliver on the aspirations of the Woodside Monash Energy Partnership, the research objectives are structured into three focused strategic research themes:

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.

ENERGY LEADERSHIP
Understanding and enabling the interplay of economics, energy security, policy and governance on the transitioning energy system, including carbon markets.

WOODSIDE MONASH ENERGY PARTNERSHIP THEME LEADERS
Each strategic research theme is overseen by Monash and Woodside Research Theme Leaders, recognised as Theme Co-Leaders.
The Theme Co-Leaders are established experts in their field, capable of attracting national and international collaborators, from academia, government and industry to support the joint ambitions of the Woodside Monash Energy Partnership.

Professor Jacek Jasieniak
New Energy Theme Leader
Monash University

Dr Jitendra Joshi
New Energy and Carbon Theme Leader
Woodside Energy

Associate Professor Akshat Tanksale
Carbon Theme Leader
Monash University

Professor Fang Lee Cooke
Energy Leadership Theme Leader
Monash University

Peter Metcalfe
Energy Leadership Theme Leader
Woodside Energy
In 2020, despite the impacts of the pandemic, the Energy Partnership and its major research programs continued to make progress. This included several projects reaching Stage 1 completion across all three strategic research themes, and expansion and planning of projects into Stage 2.

In New Energy, the seawater electrolysis program expanded into a major project for electrode design, while next stage planning in liquid hydrogen storage saw new projects being finalised for future work. Through support of the Decarbonisation Sprint, new partnerships in the Carbon Theme were developed, with work planned in carbon utilisation to commence in 2021. The Energy Leadership Theme saw the transition of work from one its first programs to a focus on policies, initiatives and market development for green hydrogen, while the next developments of the life cycle analysis saw the planning of a new tool for environmental impact and energy assessment.

2020 also saw several new multi-disciplinary teams forming across Chief Investigators and the Monash FutureLab, in addition to a number of early-stage programs commence supported by student teams.
NEW ENERGY TECHNOLOGIES

SEAWATER ELECTROLYSIS

- The majority of existing low-temperature (<100 °C) electrolyser devices cannot use seawater directly.
- This project determined the economic and technically feasible technologies for the electrolytic production of hydrogen gas from seawater.

EFFICIENT ELECTRODES

- Stage 2 of the seawater electrolysis program.
- Project will design an electrolyser capable of splitting purified sea water to H₂ and O₂, by development of electrocatalysts.
- Specific focus on the durability of new materials and overall system in intermittent mode of operation to enable efficient coupling to renewable energy sources.

Project members: Dr Alexandr N. Simonov, Professor Douglas R. Macfarlane, Dr Jitendra Joshi, Dr Dijon A. Hoogeveen, James L. Gardiner, Dr Manjunath Chatti, Dr Federico Vallana, Dr Bryan H. R. Suryanto
NEW ENERGY TECHNOLOGIES

LIQUID H₂ STORAGE

- Current liquid hydrogen storage tanks rely on complex double-shelled configurations with active cooling to minimise boil off. Critical to its operation is the need for vacuum in one of the shells to minimise thermal transfer. Scaling of such existing storage facilities presents a major challenge.

- A systematic bottom-up approach was applied to determine an ideal hydrogen storage system. This included quantitative simulations, energy models and recommendations for structural and barrier materials for cryogenic liquid storage.

Project members: Dr Tom Hughes, Professor Jacek Jasieniak, Professor Greg Sheard, Dr Ashley Roberts, Dr Chun Kiu Ng, Dr Ghazal Avijegon
CARBON CAPTURE, CONVERSION AND UTILISATION

BIOLOGICAL PRODUCTION OF 1,4-BUTANEDIOL FROM CO₂

- 1,4-Butanediol is a versatile and widely used industrial chemical for production of polymers and specialty chemicals.
- Using sugar as feedstock proof of concept, production of 1,4-butanediol by the biotechnological microorganism E. coli was investigated.

CO₂ PLANT LAYOUT

- Creation of a prototypic CO₂ plant layout using the existing LNG-focused PLO (Plant Layout Optimisation) framework.
- Model created from the data Process Flow Diagrams (PDF), adjusting equipment palette and safety/maintenance distances to CO₂ plant specifications.
- 3D models created for different parameters, orders and scenarios.
PROJECTS

CARBON CAPTURE, CONVERSION AND UTILISATION

GAS PHASE CO₂ CONVERSION

- One of the most attractive options for CO₂ utilisation into fuels and chemicals is through the conversion of CO₂ into synthesis gas (CO+H₂) via dry or tri-reforming of methane.
- However, these reactions are highly endothermic, which along with the catalyst coking problem, pose challenges for large-scale application.
- This work is determining the feasibility of novel heating to reduce the energy requirement, while incorporating state-of-the-art catalysts.

Project members: Associate Professor Akshat Tanksale, Dr Jitendra Joshi, Solomon Faka, Associate Professor Matthew Hill, Professor Kiyonori Suzuki, Dr Lee Djumas, Dr Munir Sadiq, Hamza Asmat, Ngoc Bao Khanh Chau

ACETIC ACID PRODUCTION BY CO₂ CONVERSION

- Acetic acid is produced with high conversion and selectivity over novel metal organic framework catalyst.
- Hydrocarbonylation reaction of methanol with CO₂ and hydrogen as the reactants.

Project members: Rajan Lakshman, Associate Professor Akshat Tanksale, Professor Alan Chaffee, Dr Jitendra Joshi, Solomon Faka
ENERGY LEADERSHIP

ANALYSING CHANGE FOR A LOWER CARBON FUTURE

- A life cycle assessment methodology was developed with consideration of environmental and energy flow impacts for assessment of new and emerging low energy technologies.
- Provided insights to the societal factors affecting the transition to a lower carbon future.
- Recommendations developed for governance and business strategies to assist in the energy transition.

ENERGY LEADERSHIP

GREEN ENERGY ON THE GLOBAL STAGE

- A multi-disciplinary and multi-stakeholder approach to examine inter-related thematic dimensions that will impact the future green hydrogen market with reference to specific global regions.
- Provides insights into policies, initiatives and market development for green hydrogen.
- Supports decision-making for multinational firms and international operations.

Project members: Wray Buntine, Fang Lee Cooke, Peter Metcalfe, Marc Senders, Gerry Nagtzaam, Alejandra Mendoza Alcantara, Abby Wild, Caitlin Doogan, Allie Convery, Michael Lawrence, Jingtian Wang, Nocholas Yang

Project members: Professor Fang Lee Cooke, Dr Xuan Zhu, Professor Paul Webley, Peter Metcalfe, Megan Wheeldon, Michael Lawrence, Stephan Modest
ENERGY LEADERSHIP

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.

ENERGY LEADERSHIP

ECONOMIC FAIRWAYS OF GRID-CONNECTED H₂

- Many assessments of hydrogen project viability focus on the evaluation of generic production costs independent of location.
- By assessment of geospatial factors and regional economic potential for grid-connected hydrogen projects, locations will be identified for the greatest opportunity for hydrogen development.

Project members: Stephan Modest, Professor Srinivas Sridharan, Professor Fang Lee Cooke, Peter Metcalfe

Project members: Dr Stuart Walsh, Dr Gordon Leslie, Dr Changlong Wang, Peter Metcalfe, Megan Wheeldon
ENERGY LEADERSHIP

LCA: NET ENERGY FLOWS AND ENVIRONMENTAL ASSESSMENT

- A life cycle assessment methodology developed with consideration of environmental and energy flow impacts for assessment of new and emerging low energy technologies.
- The framework enables a comparative assessment based on first order considerations of both impacts and energetics of the supply chain.

Project members: Professor Damon Honnery, Professor Andrew Hoadley, Associate Dr Roger Dargaville, Dr Graham Palmer, Peter Metcalfe, Dr Ashley Roberts, Megan Wheeldon
## KEY PERSONNEL

### ENERGY PARTNERSHIP LEADERSHIP

<table>
<thead>
<tr>
<th>NAME</th>
<th>INSTITUTION</th>
<th>ROLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Professor Paul Webley</td>
<td>Monash University</td>
<td>Energy Partnership Director</td>
</tr>
<tr>
<td>Andrea Galt</td>
<td>Woodside Energy</td>
<td>New Energy Partnership Program Director</td>
</tr>
<tr>
<td>Professor Jacek Jasieniak</td>
<td>Woodside Energy</td>
<td>New Energy Theme Leader</td>
</tr>
<tr>
<td>Associate Professor Akshat Tank Kale</td>
<td>Monash University</td>
<td>Carbon Theme Leader</td>
</tr>
<tr>
<td>Dr Jitendra Joshi</td>
<td>Woodside Energy</td>
<td>New Energy and Carbon Theme Leader</td>
</tr>
<tr>
<td>Peter Metcalfe</td>
<td>Woodside Energy</td>
<td>Energy Leadership Theme Leader</td>
</tr>
<tr>
<td>Professor Fang Lee Cooke</td>
<td>Monash University</td>
<td>Energy Leadership Theme Leader</td>
</tr>
<tr>
<td>Dr Matt Russo</td>
<td>Monash University</td>
<td>Energy Partnership Senior Manager</td>
</tr>
<tr>
<td>Justine Sik</td>
<td>Monash University</td>
<td>Senior Project Officer</td>
</tr>
</tbody>
</table>

### WOODSIDE PARTNERSHIP EXECUTIVE ADVISORY PANEL

<table>
<thead>
<tr>
<th>NAME</th>
<th>INSTITUTION</th>
<th>ROLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Professor Ken Sloan</td>
<td>Monash University</td>
<td>Deputy Vice- Chancellor and Senior Vice-President (Enterprise and Governance)</td>
</tr>
<tr>
<td>Shaun Gregory</td>
<td>Woodside Energy</td>
<td>Executive Vice President Sustainability and Chief Technology Officer</td>
</tr>
<tr>
<td>Professor Rebekah Brown</td>
<td>Monash University</td>
<td>Senior Vice Provost &amp; Vice Provost</td>
</tr>
<tr>
<td>Jason Grossan</td>
<td>Woodside Energy</td>
<td>Vice President, Technology</td>
</tr>
<tr>
<td>Professor Elizabeth Croft</td>
<td>Monash University</td>
<td>Dean, Faculty of Engineering</td>
</tr>
<tr>
<td>Professor Jordan Nash</td>
<td>Monash University</td>
<td>Dean, Faculty of Science</td>
</tr>
<tr>
<td>Professor Simon Wilkie</td>
<td>Monash University</td>
<td>Dean, Faculty of Business and Economics</td>
</tr>
<tr>
<td>Professor Ann Nicholson</td>
<td>Monash University</td>
<td>Dean, Faculty of Information Technology</td>
</tr>
<tr>
<td>Neil Kavanagh</td>
<td>Woodside Energy</td>
<td>Chief Scientist</td>
</tr>
<tr>
<td>Marcus Ward</td>
<td>Monash University</td>
<td>Chief Philanthropic Officer</td>
</tr>
</tbody>
</table>

### MONASH FUTURELAB LEADERSHIP

<table>
<thead>
<tr>
<th>NAME</th>
<th>INSTITUTION</th>
<th>ROLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Professor Chris Hutchinson</td>
<td>Monash University</td>
<td>Monash FutureLab Co-Chair, Engineering</td>
</tr>
<tr>
<td>Professor Maria Garcia de la Banda</td>
<td>Monash University</td>
<td>Monash FutureLab Co-Chair, Information Technology</td>
</tr>
<tr>
<td>Dr Sebastian Thomas</td>
<td>Monash University</td>
<td>Materials Durability Theme Leader</td>
</tr>
<tr>
<td>Dr Lee Djumas</td>
<td>Monash University</td>
<td>Research and Innovation Manager</td>
</tr>
<tr>
<td>Darren Shanahan</td>
<td>Woodside Energy</td>
<td>Production Program Manager</td>
</tr>
<tr>
<td>Andrew Lockwood</td>
<td>Woodside Energy</td>
<td>Data Science Adviser</td>
</tr>
<tr>
<td>Jason Hill</td>
<td>Woodside Energy</td>
<td>Monash FutureLab Manager</td>
</tr>
</tbody>
</table>
FURTHER INFORMATION

DR LEE DJUMAS
Research and Innovation Manager
Woodside FutureLab
Monash University
lee.djumas@monash.edu

DR MATT NUSSIO
Senior Manager
Woodside Monash Energy Partnership
Monash University
matthew.nussio@monash.edu

ANDREA GALT
New Energy Partnership Program Director
Woodside Energy
andrea.galt@woodside.com.au

PROFESSOR KEN SLOAN
Deputy Vice-Chancellor and Senior Vice-President
(Enterprise and Governance)
Monash University
ken.sloan@monash.edu