



THE UNIVERSITY
OF QUEENSLAND
AUSTRALIA

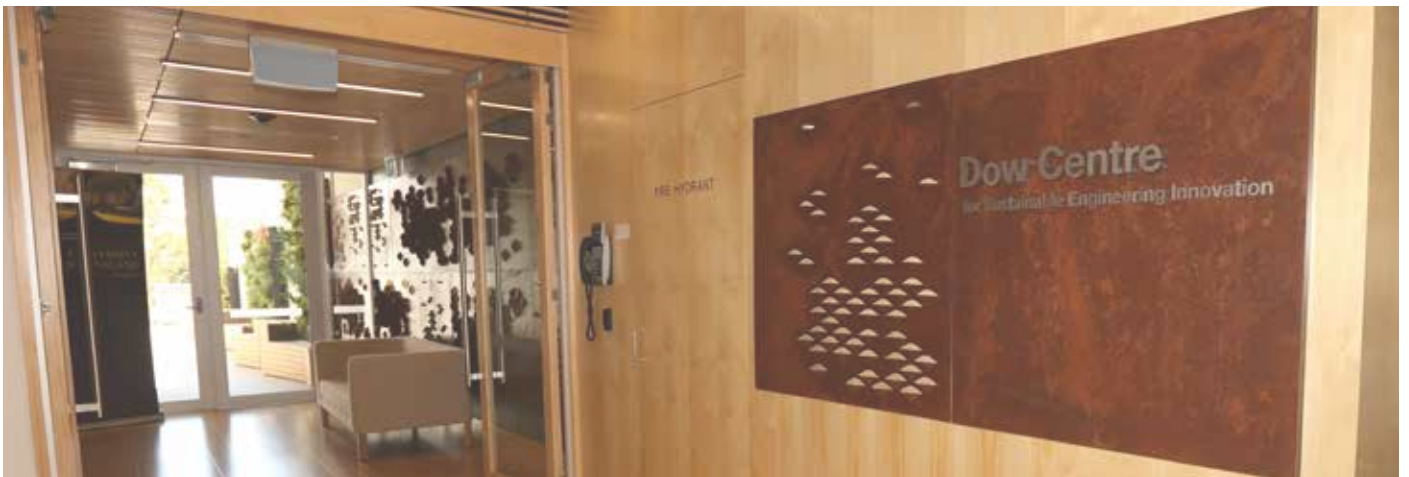
CREATE CHANGE

DOW CENTRE FOR
SUSTAINABLE ENGINEERING INNOVATION

ANNUAL REPORT 2018



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Messages



Message from the Vice-Chancellor and Chair of the UQ Dow Centre Advisory Board

*The Centre seeks to foster
and facilitate innovations in
economically and environmentally
sustainable processes associated
with the production and use of
energy and materials.*

I am pleased to introduce the 2018 Dow Centre for Sustainable Engineering Innovation Annual Report, in my role as chair of the Dow Centre Advisory Board.

UQ's new strategic plan came into effect in 2018 with our collective vision for **knowledge leadership for a better world**. It is about creating change that will cultivate the next generation of innovators and support work to push the frontiers of economically and environmentally sustainable research with global impact.

The Dow Centre has always had this tenet at its core. The Centre seeks to foster and facilitate innovations in economically and environmentally sustainable processes associated with the production and use of energy and materials.

The Dow Centre's impact is seen in Australia and globally, as is evidenced by the Rapid Switch Project led by the Dow Centre Director and Dow Chair in Sustainable Engineering Innovation, Professor Chris Greig. Rapid Switch seeks to understand pathways to decarbonise the world's energy systems, arguably one of the most critical challenges we face in coming decades. The Dow Centre has continued to demonstrate global leadership in response to this challenge, through expanding and strengthening our strong partnerships with Princeton and Carnegie Mellon universities in the United States and with a growing network of academic and industry partners in China, India and worldwide.

I was pleased to announce in July 2018 that the Dow Chemical Company, which provided the Centre's initial US\$10 M seed funding in 2012, had committed a further \$4.4 M to the Centre. This generous funding will continue to power research into sustainable production and use of chemicals, energy, transport, and other key areas.

Dow's investment in UQ builds on our longstanding partnership that has already delivered novel research in low-carbon dioxide emission steel production, clean energy, and next-generation fertilisers that decrease environmental degradation. These could have a positive impact on the Great Barrier Reef.

Research projects that deliver solutions to globally significant challenges through the generation of new knowledge continue to resonate in our community. Longstanding UQ supporters Trevor and Judith St Baker have spearheaded multiple philanthropic initiatives at the University that focus on building breakthrough technologies in energy, transport and healthcare. In 2018, The Trevor and Judith St Baker Family Foundation generously donated \$1.5 M to establish The Tritium Visiting Fellowship in Electro-Mobility.

The Tritium Fellow will become an integral part of the Dow Centre and will lead research activities directed towards advancing the performance, economics and uptake of "e-Mobility" globally. The research will link public policy, investment decisions, technology innovation, public health studies and community behaviour in support of the transition to sustainable, low-emission, electric-powered transportation, contributing to the international Rapid Switch project research objectives. This Fellowship is testament to the large-scale change that UQ is making possible through philanthropic partners such as the St Bakers, who are helping to drive renewable energy initiatives that advance a more sustainable and prosperous world.

The Centre also continues to contribute to the University's teaching and learning outcomes. In 2018, Centre leaders supervised 67 PhD, MPhil and undergraduate thesis students, of whom 42 were contributing to Dow Centre projects or related research to create a more sustainable future. Dow Centre research and teaching staff demonstrated their commitment to developing the next generation of leaders in sustainability, by coordinating, leading, lecturing and tutoring in some 13 undergraduate and postgraduate courses equipping students with knowledge and skills spanning engineering modelling and problem solving, energy systems and renewable energy, to professional practice skills to enable graduates to thrive in the modern business environment.

On behalf of the Advisory Board, I congratulate Professor Greig on successfully guiding the Dow Centre toward its objectives again in 2018. I also thank the entire Dow Centre team, and their UQ, industry and government collaborators and partners, for their vital contributions in the past year.

Finally, I thank the Dow Chemical Company for its continued generous investment and support and The Trevor and Judith St Baker Family Foundation, which has enabled the Dow Centre to flourish in 2018.

*Professor Peter Høj AC
Vice-Chancellor and President,
The University of Queensland*

Director's Report

Securing the future

Now entering our sixth year, 2018 marked the end of the original five-year term of the very generous gift from the Dow Chemical Company. This past year therefore represented both an important milestone and a critical transition to shore up our future. To this end, I am pleased to report that 2018 was indeed punctuated with several significant successes that have provided the foundation to underpin our continued contributions to research and teaching at UQ.

As noted in the Vice-Chancellor's introduction, perhaps the most significant outcome in 2018 was the decision by the **Dow Chemical Company** to extend its generous support. The Dow Centre hopes that this generous gift will inspire others to invest in research focussed on sustainability, energy and materials.

A second notable attainment was structuring an **Endowment for the Dow Centre Director** in perpetuity. This both assures the future of the Dow Centre and enhances the prospects for attracting an outstanding person to succeed me as Director.

Finally, I am absolutely delighted to acknowledge the very generous gift from the Trevor and Judith St Baker Family Foundation. This gift of \$1.5 M, will be used to support the **Tritium Visiting Fellowship in Electric Mobility** at the Dow Centre. The fellowship will fund early- to mid-career researchers undertaking research to accelerate the global transition to electrified transportation.

The Centre also recorded some important wins on the competitive grant front. In last year's Annual Report, we noted that Dow Centre researchers were involved in two separate Cooperative Research Centre (CRC) bids. It is very satisfying to report that both bids were successful, and in late 2018, the Fight Food Waste CRC and the Future Fuels CRC both commenced.

The Fight Food Waste CRC aims to reduce Australia's food waste problem, currently estimated to be worth \$20 billion per annum. The CRC will undertake research to improve efficiencies across the supply chain, develop innovative processes to create value added products from unavoidable waste, and explore opportunities to change practices by engaging with industry and consumers. Three key research programs will investigate:

1. *Reducing Supply Chain Losses*
2. *Transforming Waste Resources*
3. *Education and Behavioural Change*

Dow Centre researchers Bronwyn Laycock, Paul Luckman, and Joe Lane will be involved in this CRC; they will be part of a consortium of 46 industry and ten research partners working to eliminate food waste.

The Future Fuels CRC aims to position the Australian gas and pipeline industry to provide competitive, low-carbon energy alternatives for residential, commercial, industrial and transportation sectors, which complement and support the trend to increasing variable renewable electricity generation. Research teams will develop processes and infrastructure solutions, governance guidelines and stakeholder engagement strategies, which enable the production, distribution and utilisation of low carbon fuels in the near, medium and longer term. The three key research programs will investigate:

1. *Future fuel technologies, systems and markets*
2. *Social acceptance, public safety and security of supply*
3. *Network lifecycle management*

Dow Centre researchers Simon Smart, Chris Greig, Mojgan Tabatabaei, and Rijia Lin will be involved in this CRC. They will focus on techno-economic modelling of fuel production processes, and undertake ground-breaking research on molten



At the heart of our approach is an applied, multi-disciplinary focus, assuring projects are subjected not only to technological rigour, through modelling and/or experimental research, but that they can also be cost-competitive

metal methane pyrolysis for zero-CO₂ hydrogen production.

These projects will add to the Dow Centre's innovative research outputs, and will complement the Dow Centre's three flagship programs. I look forward to monitoring their progress and to reporting on their future successes.

Our research strategy continued to focus on a small number of flagship projects that hold the potential to have global impact. At the heart of our approach is an applied, multi-disciplinary focus, assuring projects are subjected not only to technological rigour, through modelling and/or experimental research, but that they can also be cost-competitive. We must also connect our research with industry and society. To date the flagship projects have generated considerable interest among a range of stakeholders in industry and government. In the year ahead, we will focus on converting that stakeholder curiosity to meaningful partnerships.

The **Rapid Switch project** will provide critical technology- and region-specific insights to guide decision making by both policy makers and investors in the low-carbon energy transition. The Intergovernmental Panel on Climate Change, the International Energy Agency, and other institutions outline scenarios for a low-carbon transition. Such reports all lack a critical focus – they do not speak to the pace at which decarbonisation could realistically occur given the state of technologies, and political, social, and economic constraints in various regions.

Rapid Switch aims to fill this gap by critically analysing bottlenecks and unintended consequences that may arise during transitions, and resolving them sector-by-sector and region-by-region. By doing this in ways that respect local values and conditions, the collaboration aims to identify the most viable transition pathways and realistic pace. This means conducting locally-informed, deep-dive analyses of proposed energy transitions for specific sectors in specific countries. Currently partnering with Princeton University, Carnegie Mellon University, Tsinghua University, IIT Bombay and IIT-Delhi, these partnerships, with shared approaches and frameworks are central to delivering on our ambition. We plan to expand our geographic horizon in the near future.

On the materials front, our **low-CO₂ production of iron** process in which iron ore is reduced using hydrogen (from methane pyrolysis) in molten salts and metals, continues to show great promise. The process yields solid iron, solid carbon and no CO₂. The intended impact is a next generation steel making process which does not generate greenhouse gas emissions.

In 2018, we achieved proof-of-concept of the individual unit processes and completed a comprehensive process model and techno-economic analysis. We consider the process to have now achieved (Technology Readiness Level) TRL-4 and the techno-economic analysis continues to indicate that it will be substantially more competitive than the current default alternative for decarbonising the steel industry, namely carbon capture and storage (CCS).

Finally, **our low-CO₂ production of hydrogen and fuels** research which is developing new processes for the production of hydrogen, syngas and other related energy carriers also made steady progress. Like the iron production research, this project relies on methane (natural gas) pyrolysis in molten salts and metals without CO₂ production. The intended impact is a suite of future fuels and chemicals processes, which are generated with few or no greenhouse gas emissions. The hydrogen work has been boosted as a result of our success as a participant in the Future Fuels CRC.

A further opportunity, identified in 2018, adapted this process to convert methane-CO₂ mixtures into hydrogen-rich syngas which is a critical feedstock for many petrochemical products. A significant opportunity with this process would be the potential to monetise currently unviable CO₂ rich natural gas resources. Our initial analysis indicates that it could offer a substantial competitive advantage over conventional approaches, which separate (using amine scrubbing technology) and geologically sequester the CO₂.

I encourage you to read further to learn about these flagship and next generation projects.

Last but not least, I am always proud to reflect on the Dow Centre's continued strong commitment to educate students, the future innovators and leaders, in the Faculty of Engineering, Architecture and IT. The accomplishments of the Dow Centre could not have been achieved without students who make significant contributions to our research outputs. And these same students, as graduates, will go into research institutes, industries and take roles in government that will continue to shape sustainable practices.

Our success through 2018 comes with the strong support and counsel of our Advisory Board which is chaired by UQ's President and Vice-Chancellor, Professor Peter Høj. I also acknowledge the contributions of all advisory board members including Louis Vega, Managing Director of Dow Australia and New Zealand, Dr Weiguang Yao (CTO, Dow China), Noel Williams and UQ colleagues.

I would also like to thank our former Centre Manager Ms Celestien Warnaar for her contributions during our first five years and acknowledge our new Centre Manager, Ms Briony Beaumont for her outstanding work in managing the Dow Centre's operational, engagement and support activities.

Finally, I would like to thank all Dow Centre staff for their continuing support and contributions to our success in 2018. I look forward to continuing to work with such talented people.

Professor Chris Greig

Director and Dow Chair in Sustainable Engineering Innovation.

Key outputs 2018

Research



8

Ongoing projects

2

Successful
CRC bids

39

Peer reviewed
publications

67

PhD, MPhil and
Undergraduate Thesis
students supervised

42

Student projects part of
or related to Dow Centre
projects

Engagement



39

External organisations visited the
Centre, representing industry, other
Universities, Government, or CRCs

77+

External organisations were visited
or met with by Dow Centre staff

47+

Speaking and engagement events
including keynotes, media interviews
and symposiums

12

Australian collaboration partners,
comprising other Universities,
industry, government and CRCs

15

Collaboration partnerships
with UQ entities

Student experience



13

Undergraduate and postgraduate
courses coordinated, lectured or
tutored

1600+

Students reached through
teaching

4

Summer Research Program
students hosted

26

Teams entered the SISCA
competition

33

Students awarded SISCA prizes

Global engagement



International collaboration across **14** countries

- Belgium
- Cambodia
- Canada
- China
- Germany
- India
- Indonesia
- Italy
- Japan
- Kuwait
- Nepal
- Papua New Guinea
- South Africa
- USA

People

Advisory Board

The Dow Centre Advisory Board is chaired by Vice-Chancellor and President Professor Peter Høj AC, and is comprised of senior representatives from industry and the University of Queensland.

The Advisory Board provides expert advice and insight to inform the Dow Centre's research agenda. The Board plays an important role in connecting Dow Centre researchers with international thought leaders in government, business and civil society, as well as helping to secure support from a range of philanthropic, commercial and competitive sources to advance the work of the Dow Centre.

The Board meets at least three times each year. In 2018, the Dow Centre Advisory Board met on, 16 March, 14 June and 17 October.



Professor Peter Høj AC
Vice-Chancellor and President, The University of Queensland

Professor Peter Høj commenced as Vice-Chancellor and President of The University of Queensland on 8 October, 2012. Prior to this appointment Professor Høj was Vice-Chancellor and President of The University of South Australia (2007-2012). Before that, he was Chief Executive Officer of the Australian Research Council (2004-2007) and Managing Director of the Australian Wine Research Institute (1997-2004). He is a member of the Medical Research Future Fund Advisory Board. He was educated at the University of Copenhagen, majoring in biochemistry and chemistry, and has a Master of Science degree in biochemistry and genetics, a PhD in photosynthesis, an Honorary Doctorate from the University of Copenhagen and an Honorary Doctorate from the University of South Australia. He is a Fellow of the National Academy of Inventors in the USA, a Fellow of the Australian Academy of Technological Sciences and Engineering and a Foreign Member (Natural Sciences Class) of The Royal Danish Academy of Sciences and Letters.



Professor Ove Hoegh-Guldberg FAA
Director, Global Change Institute, The University of Queensland

Professor Ove Hoegh-Guldberg is Professor of Marine Science at The University of Queensland. In addition to leading research groups focussed on the influence of global climate change on marine ecosystems, Professor Hoegh-Guldberg is Director of The Global Change Institute at the University. The Institute is focussed on supporting and building research programs into the key challenges facing our changing world. Current focal points include clean energy, food systems, healthy oceans and sustainable water as well as the drivers such as climate change, technological innovation and population growth. Professor Hoegh-Guldberg is currently an ARC Laureate Fellow, a member of the Australian Academy of Science and a Coordinating Lead Author for the UN Intergovernmental Panel on Climate Change.



Professor Peter Halley
Head, School of Chemical Engineering, The University of Queensland

Professor Peter Halley is Head of the School of Chemical Engineering, the Director of the Centre for High Performance Polymers (CHPP), a chief investigator in the Advanced Materials Processing and Manufacturing (AMPAM) Centre and an Affiliate Professor in the Australian Institute for Bioengineering and Nanotechnology (AIBN). Professor Halley is a Fellow of the Institution of Chemical Engineers (IChemE) and a Fellow of the Royal Australian Chemical Institute (RACI). Professor Halley is on the editorial board of Green Materials, Plastics, Rubbers and Composites, Starch and the Journal of Renewable Materials. Professor Halley also sits on the board of the UQ RT Bauxite and Alumina Technology Centre, and the HBIS Sustainable Steel Innovation Centre.



Professor Alan Rowan
AIBN Director and Group Leader, The University of Queensland

Professor Rowan, a current ARC Laureate Fellow, studied at the University of Liverpool, obtained first class honours in chemistry, and was awarded the Leverhulme Medal. He obtained his PhD degree at the same university working on the self-assembly of chlorophylls. He subsequently worked for two years in New Zealand with Prof Chris Hunter in the area of catenane and rotaxane self-assembly. He returned to Europe as a Marie-curie Fellow to work with Prof Roeland Nolte at the University of Nijmegen the Netherlands, where he continued research in functional supramolecular assemblies. He stayed in Nijmegen and became full professor in 2005, where he established a new group in molecular materials, studying the relationship between molecular assembly and functional properties. In January 2016 he left the Netherlands and became Director of the Australian Institute for Bioengineering and Nanotechnology at UQ.



Mr Louis Vega
President and Managing Director, Australia and New Zealand and Vice President Olympic and Sports Solutions, Dow Chemical Company (Dow)

President Olympic and Sports Solutions, Dow Chemical Company (Dow) Louis Vega joined Dow in 1998 and has advanced through a variety of roles in the Company in Horgen, Washington D.C., Dubai, Midland and New York. Mr Vega started his career with progressive roles in Washington, DC; from Capitol Hill to the Executive Branch, over the span of 12 years. He has a degree in Government and Public Relations from New Mexico State University in Las Cruces, New Mexico and currently resides in Melbourne, Australia.



Dr Weiguang Yao
Global Director, Asia Pacific Chief Technology Officer, The Dow Chemical Company

Dr Weiguang Yao is the Chief Technology Officer for Asia Pacific R&D. He is responsible for AsiaPacific R&D Strategy to ensure Asia-Pacific Resources align with regional growth opportunities. He represents Dow R&D in the Asia-Pacific region. He also takes responsibility as Board Director of East China University of Science and Technology. Dr Yao is based in Shanghai. Dr Yao joined Dow in April, 2007 as Sr. R&D Director for Dow Core R&D in Asia-Pacific. He was responsible for building AP core and business aligned research capability and strategy at Dow, driving AP core R&D innovation for regional growth.



Mr Noel Williams
Specialist Manufacturing Advisor, (Alumni Representative)

After a career with Dow spanning 36 years as a Chemical Engineer and later as a senior executive, Mr Noel Williams now works in consultancy as a Specialist Manufacturing Advisor and on charitable not for profit boards. Most recently in his career at Dow, Mr Williams was appointed as Vice President to lead Dow's Business Development efforts in Asia Pacific, while previously he had been President of Dow in South East Asia, Australia and New Zealand, all based in Singapore. Mr Williams is a past Chairman of the Board of the Institution of Chemical Engineers (IChemE) in Australia and was a Governor and Treasurer of the American Chamber of Commerce in Singapore. He is a past President and Director of the Australian Plastics and Chemicals Industry Association (now Chemistry Australia). Mr Williams also serves as chairman on the UQ School of Chemical Engineering Advisory Board.



Centre staff

The Dow Centre continues to flourish in large part due to the commitment and leadership demonstrated by its staff.

In 2018, a number of staff from the Centre were honoured in recognition for their contributions as teachers, supervisors, researchers, and leaders within both the UQ and global research communities.

In early 2018, Professor Chris Greig was selected as the 2018 Gerhard R. Andlinger Visiting Fellow in Energy and Environment at Princeton University's Andlinger Center for Energy and Environment (ACEE).

The visiting fellows program invites distinguished visitors to contribute to, and enrich, research and teaching within the Andlinger Center.

This prestigious position seeks to bring different perspectives and urgency to the work of the Andlinger Center, specifically regarding energy and environmental challenges.

Commencing in July 2018, the purpose of Chris' fellowship is to focus on building the Rapid Switch project to its full potential, including leading an international Rapid Switch Workshop in 2019.

In December 2018, Simon Smart received the 2018 EAIT Faculty Teaching and Learning Excellence Award in recognition of his contribution to the development of EAIT curricula, contribution to learning outcomes of students within the Faculty, and enhancement of the student experience.

Bronwyn Laycock was commended for her outstanding contribution to individual supervision and enhancing the research supervision culture within the EAIT Faculty, receiving the 2018 HDR Supervision Excellence Award with A/Prof Steven Pratt. Additionally, Bronwyn won a 2018 ARC Discovery grant on CO₂ to biopolymer conversion.

Both Simon Smart and Bronwyn Laycock were promoted to Associate Professor in late 2018, to formally commence in January 2019.

Professor Lianzhou Wang was awarded a UQ Excellence in Higher Degree by Research (HDR) Supervision Awards, one of only four awards conferred to UQ staff in 2018. This award reflects outstanding performance in the supervising, mentoring, and training of HDR candidates.



24 Total research and professional staff engaged as Dow Centre team members throughout 2018

2 Promotions to Associate Professor

3 Prestigious teaching and supervision awards

1 New industry-supported Chair

1 New philanthropically supported Fellowship

1 ARC Discovery Grant

Senior staff



Professor Chris Greig, Director

Chris Greig is a Professor of Chemical Engineering and Director of the Dow Centre for Sustainable Engineering Innovation. He was previously the inaugural Director of the UQ Energy Initiative from 2011 to 2017.

Chris obtained his degree Chemical Engineering and his PhD at the University of Queensland. He is a Fellow of the Australian Academy of Technological Sciences and Engineering and a past recipient of the Fluor Chemeca Award for Excellence in Engineering Management.

His 26-year industry career commenced as the founder of a successful process technology and contracting company, which was later sold to a major international engineering company. Since then and prior to joining UQ, he held senior project, executive and non-executive director roles in the resource and energy industries.

Chris' teaching activities include Professional Practice in the Business Environment for final year and Masters level engineers; and Masters course called Energy Finance and Investment. His main research interests at UQ lie in Energy Transitions, Economics and Policy, Energy for Development, Mega-Project Implementation and CCS.



Associate Professor Simon Smart

Simon Smart is a Principal Research Fellow in the Dow Centre and an Associate Professor in the School of Chemical Engineering at The University of Queensland. Prior to becoming a Lecturer, Simon worked for four years within the Films and Inorganic Membrane Laboratory (FIMLab) at UQ, and since August 2018, continues as the Director of its latest incarnation, the Functional Interfacial Materials and Membranes Laboratory (FIM2Lab). Simon was the secretary for the Membrane Society of Australasia from 2011 - 2013, where he served on the board of directors from 2010 – 2014. He is actively involved in teaching at the undergraduate and masters level, delivering courses in Energy Systems, Energy Principles and Renewable Energy and Engineering Innovation and Leadership. Simon is currently leading the Dow Centre's flagship projects into low CO₂ production of materials and chemicals and contributes to the Rapid Switch initiative.



Associate Professor Bronwyn Laycock

Bronwyn Laycock is a polymer scientist with an interest in advanced materials for sustainability. She is currently working across a range of projects, including novel biopolymers and their composites, particularly waste derived, and the applications of these in controlled release formulations (for fertilisers, agricultural chemicals, and veterinary applications). She also has projects in self-assembled conducting peptides, spinifex to carbon fibre conversion, hydrogels for nutrient management, lignin-based polyurethane foams and waste to diesel conversion. Within the Dow Centre she is delivering the Next-Generation Fertiliser program, and has been instrumental in bringing the Fight Food Waste Transformation program in the Fight Food Waste CRC to the Dow Centre. Bronwyn continues to pursue innovation in areas that will make a step change contribution to sustainability, such as in cost-effective nutrient management, food waste management and recovery, and delivering solutions for plastic use in the circular economy.



Professor Lianzhou Wang

Lianzhou Wang is currently a Professor in the School of Chemical Engineering, Director of the Nanomaterials Centre (Nanomac), and a Senior Group Leader within the Australian Institute for Bioengineering and Nanotechnology (AIBN) at UQ. He received his PhD degree from Shanghai Institute of Ceramics, Chinese Academy of Sciences in 1999. Before joining UQ in 2004, he worked at two leading national research institutions (NIMS and AIST) in Japan as a Research Fellow for five years. Since joining UQ, Lianzhou worked as an ARC Queen Elizabeth II Fellow, Senior Lecturer, and Associate Professor, prior to becoming an ARC Future Fellow and Professor in the School of Chemical Engineering and Nanomac. As co-Chief Investigator of the Flexible Printed Batteries CRC-P, Lianzhou leads and oversees laboratory research based at the AIBN.



Professor Stephen Wilson

Professor Stephen Wilson is leading the global economic modelling component of the Rapid Switch project with the Dow Centre. In 2018, Stephen was appointed as a Professor in the School of Mechanical and Mining Engineering, where he directs energy-related research in the newly formed Centre for Energy Futures. Research in the Centre for Energy Futures ranges from solar thermal generation and supercritical CO₂ cycles to simulation of proposed designs for inertial and magnetic fusion reactor containment. Stephen teaches Professional Practice to final year undergraduate engineers, as well as international Masters students from all engineering schools in the faculty. In addition, Stephen teaches a Masters-level course on Energy Markets, Law and Policy, which he developed in 2017. Stephen is a key member of the Rapid Switch team at UQ, and is the Principal Supervisor or Co-Supervisor of PhD students contributing to the Rapid Switch project.



Associate Professor Simon Smart

Simon Smart is pursuing the big challenges around sustainability for energy and materials.

After completing his Bachelor of Engineering (Chemical) / Bachelor of Science at UQ, Simon Smart was hooked on how engineering can change lives. His initial interest in biomedical engineering led to a PhD in materials science in 2008 and the inspiration to pursue opportunities to positively impact on the lives of others.

During the early days of his research career, Simon used his material science background to develop new membranes for gas separation, and in particular, carbon capture and storage. It was through this research that he developed a deep interest in the world's energy systems, and specifically, the impact of anthropogenic drivers of climate change on both natural systems and human society, and by extension, the complex relationship between climate change mitigation and sustainable development.

With an appreciation of the scale of our climate/energy challenge, Simon became involved in educating UQ's undergraduate cohort about energy systems and sustainability as a Lecturer (and later Senior Lecturer) within the Faculty of Engineering, Architecture and Information Technology (EAIT).

Seeing the potential for this emerging area of study to inspire change among students, Simon helped to expand the curriculum by developing ENGY4000 - Energy Systems - which

today provides students with an understanding of global energy systems including energy production from renewable and non-renewable resources in the context of decarbonising the world's economy to mitigate climate change. Inspired by his students' avid interest in sustainability and hunger for knowledge, Simon looked to enhance the learning experience, designing his courses to maximise student interaction, workshops, and mentoring.

"Our engineering students bring a lot of optimism and enthusiasm to the UQ community. They are not constrained in their thinking, and so are able to bring fresh perspectives and ideas to our discussions – this environment is energising for both students and teaching staff alike," Simon said.

"Furthermore, engineers from chemical, mechanical, IT and power systems disciplines all think differently and bring unique strengths to the workforce. By ensuring our courses integrate a variety of fields and experience levels, I want to help our students learn to work effectively together across disciplines, and become effective problem-solvers ready for a career in research or industry that has impact."

By expanding both the content and reach of these courses, Simon aims to encompass the entire spectrum of energy projects and inspire future generations of engineers to pursue

a career in sustainability. Simon is also keenly aware of the need to align university coursework with current and future needs of industry.

“It is essential that we continue to closely align engineering research and teaching, with industry needs”, he said. “And in fact the way I see it – Research informs my teaching, and teaching informs my research – it is a cyclical process”.

Throughout his teaching career, Simon has witnessed a growing interest in how innovative ideas are formed, how innovation occurs, and how engineers can develop sustainability-related ideas to become commercially viable, and now hopes to foster this curiosity among his students.

ENGG7902 - Engineering Innovation and Leadership - is an example of this thinking put into practice. Drawing inspiration from the undergraduate ENGG4900 - Professional Practice and the Business Environment - which was developed by Dow Centre Director Professor Chris Greig, ENGG7902 fosters innovation and entrepreneurship in the Masters of Engineering students, by tasking them with creating a small engineering start-up whose technology must address a real world problem. Working through the Business Model Canvas the students develop skills to engage and influence innovative practice in their own engineering contexts.

Building on the strong project-centred curriculum within the School of Chemical Engineering, Simon's commitment to his students was recognised by an EAIT Citation for Excellence in Student Learning in 2016, as well a Teaching and Learning Excellence Award in 2018.

Since becoming a member of the Dow Centre in 2015, Simon has honed the focus of his research toward the more applied, scalable industrial processes and engineering technologies that have the potential to make a significant impact on the broader society. Promoted to Associate Professor at the end of 2018, Simon currently leads a research program geared toward the Dow Centre's mission of pursuing solutions to globally significant challenges.

Simon also appreciates the important role that universities can play in policy-making, having recently been engaged by the Queensland Government as the Energy Sector expert to contribute to the development of the Queensland Climate Adaptation Plan for the industries and resources sector.

“We must continue to be forward-looking and innovative in our research, while remaining closely aligned with industry and societal needs, to produce technologies which are both relevant and able to be demonstrated at an industrial scale”, he said.

This interest led Simon help prepare a successful bid for the Future Fuels CRC, which is an industry-led, collaborative approach to research which seeks to transition Australia toward the use of clean fuels such as hydrogen.

Simon now leads a research program at the Dow Centre evaluating new technologies. This specifically involves re-imagining how we produce essential infrastructure and materials, for example fuels, steel and cement.

“These industries are among the most challenging to decarbonise – but also among the most important for societal growth and prosperity.”

Simon believes that through partnered innovation, real change is possible.

“We welcome opportunities to join with other researchers and industry partners who share this goal”.

As a supervisor and mentor to numerous undergraduate and postgraduate students at UQ, Simon feels optimistic about the future generation of researchers, and recognises the value that they can bring to society, industry and business. Encouraging his students to gain global experiences and perspectives, he hopes his students and colleagues at UQ will become leaders in their fields.

“Through a combination of cutting-edge technology and a global perspective, researchers and students at the Dow Centre become well-equipped to advance ideas that benefit the world.”

It is essential that we continue to closely align engineering research and teaching, with industry needs.

Professional staff and collaborators



Ms Briony Beaumont, Centre Manager

Briony joined the Dow Centre for Sustainable Engineering Innovation in July 2018 as the Centre Manager. In this role, Briony is responsible for supporting the Director and Advisory Board, contributing to the implementation of Centre strategic initiatives, and overseeing all operational matters within the Centre. This includes operational planning and reporting, budget management, coordination of professional support services, and engagement with Dow Centre stakeholders. Briony holds a Bachelor's degree in Business Management from the University of Queensland, and has a professional background in business-management and governance roles. Briony is also currently completing a Masters of Business Process Management with a view to further supporting operational efficiency within the Centre. As Centre Manager, Briony provides a key interface for the Centre's internal and external stakeholders.



Dr Jannie Grové, Research Project Manager

Jannie is a chemical engineer who has, over a 25+ year period, gained broad experience in project evaluation, development, process design, implementation, commissioning and operation of chemical plants / projects in South Africa, the USA and Australia. Specific industry experience in the oil shale, coal-to-liquids, cement, alumina, vinyl chloride monomer and ethylene production industries included roles at senior and executive management levels, primarily focussed on project development and the management of operations. His formal qualifications include a master's degree in Chemical Engineering from the University of Pretoria (South Africa) and a PhD from the University of Queensland (Australia). He also holds an MBA from Northwest University (South Africa), in which he graduated top of the class and received the Old Mutual Gold Medal for outstanding academic achievement. In addition to external consulting, Jannie lectures and tutors at UQ and currently assists with the management of the Printed Energy CRC project on a part-time basis.



Ms Mojgan Tabatabaei, Techno-economic Analyst

Mojgan received her Bachelor of Engineering degree in chemical engineering and was awarded top student rank from Iran University of Science and Technology in 1993. As a graduate engineer, she joined the Air Quality Control Company in the position of environment engineer focusing on air pollution, establishing air monitoring facilities in Tehran with collaboration of international organisations including the World Bank and the World Health Organization. She then went on to earn her Master of Engineering degree in chemical engineering from Tehran University, Iran in 1997 and joined the Islamic Azad University as an academic staff. Mojgan has been involved in Front End Engineering Design and detailed design engineering of several mega scale industrial projects in a role of lead and principal process engineer from 2000. She joined the Dow Centre in 2014 as a Techno-economic Analyst of various conceptual design processes .



Dr Howard Fong, Collaborator

Howard has broad and deep knowledge of the petrochemical industry and specialises in new technology assessment, development and commercialisation, functioning at the interface between technology and business. He is the holder of over 30 patents and several of the major developments he helped initiate and champion were piloted and commercialised.

Howard continues to consult with major international as well as start-up companies in vastly different technology fields, identifying opportunity spaces, providing critical techno-economic evaluations, and charting the path for successful commercialisation.

Research staff



Dr Joe Lane, Research Fellow

Joe is a Research Fellow, with a professional background spanning process engineering, water resource planning and environmental management. Prior to joining the Dow Centre, Joe led the UQ contribution to the development of the Australian Industrial Ecology Virtual Laboratory, a collaboration between ten different Australian research groups, developing innovative tools for coupled environmental-economic analysis. Joe managed the Dow Centre interactions with the Brisbane Airport Corporation and reviewed opportunities for solutions to sustainability challenges associated with water and plant nutrients management. Currently he is working in the Rapid Switch team, as well as involved with the CRC bid *Fight Food, Waste and Fraud*.



Dr Paul Luckman, Research Fellow

Dr Luckman is a Chemical Engineer from the University of Queensland, with a Masters in Biological Engineering and a PhD in Biomaterials Engineering. Paul specialises in bio-polymer process engineering materials and technologies. Dr Luckman has worked on the boundary between academia and industry with a range of companies from start-ups to several of the world's largest users and manufactures of biopolymers to develop product solutions for a range industry sectors such as packaging, agriculture, mining, and food. His research career to date has been entirely collaboratively funded through industry-linked projects including Collaborative and Industry Engagement Fund, two ARC-Linkages, an Advance Queensland Innovation Partnerships, and is currently an Advance Queensland Research Fellow. Dr Luckman is currently contributing to the Dow Centre's research as the Program Leader for the Transform Program with the Fight Food Waste Cooperative Research Centre.



Dr Miaoqiang Lyu, Research Fellow

Miaoqiang obtained his PhD degree from School of Chemical Engineering in 2017, and commenced as a post-doctoral research fellow working on the *Advanced Printing Technology for New Generation Flexible Batteries CRC-P* in early 2018. He is experienced in material synthesis, characterisations and applications, in particular renewable energy generation and storage areas. In 2018, Miaoqiang was the recipient of an Advance Queensland Industry Research Fellowship (Early Career), and is currently working toward developing printable and self-powered electronics for Internet of Things (IoT) devices.



Dr Taiwo Odedairo, Research Fellow

Taiwo joined the Dow Centre for Sustainable Engineering Innovation as a Postdoctoral Research Fellow in 2017. Taiwo's research interest is focussed on novel materials for production of sustainable and environmentally friendly chemicals/fuels and power in the real world industrial processes. He currently works on dual-phase catalytic system for low-cost petrochemical CO₂ utilisation and high-CO₂ content natural gas fields. He received his Bachelor and Master of Science in Chemical Engineering from Obafemi Awolowo University, Nigeria and King Fahd University of Petroleum and Minerals, Saudi Arabia, in 2006 and 2010, respectively. Prior to his PhD, he worked for two years with Saudi Arabia Basic Industries Corporation (SABIC), a leading petrochemical company. He is an inventor of four granted US Patents, with another four currently pending. He has also published over 25 scientific papers and currently serves as a reviewer for several research journals. He was awarded his PhD in Chemical Engineering from The University of Queensland (UQ), Australia in 2016.



Dr Martin Stringer, Research Fellow

Martin Stringer is a theoretical astrophysicist who's mounting concern for our own planet has brought him back down to earth to work on terrestrial problems, applying mathematical modelling techniques developed over a ten year career studying galaxies to analyse the stability and sustainability of ecosystems and - now - future systems of energy generation. Martin began working at the Dow Centre in June 2017, contributing to all projects within the Rapid Switch theme.



Dr Luigi Vandi, Research Fellow

Luigi Vandi is a Research Fellow with a diverse background in Materials Science. His translational research activities have a strong focus on industry relevant projects, including high-performance composites manufacturing for automotive and aerospace applications. His current focus and expertise is in biocomposites and biopolymers innovations for sustainable developments. In his role at the Dow Centre, Luigi is focusing on the materials development for next generation fertilizers. Successful outcomes would address a global issue with nitrogen and phosphorous losses in agriculture. Being part of a multidisciplinary team at the Dow Centre with a worldwide vision on sustainability, energy and waste management is something, which he finds very valuable and stimulating.



Dr Khuong Vuong, Research Fellow

Khuong completed his PhD at the University of New South Wales in the area of organometallic chemistry and catalysis. Khuong has since worked as a researcher at several universities and research institutes in Australia and overseas. He has participated in a number of successful collaborative projects and has experience in synthetic chemistry, high temperature processes, catalysis, photo-chemistry and biomass conversion. Khuong joined the Dow Centre in 2015 and has worked on several projects including Low CO₂ Iron Production project. He is now completing his Master of Environmental Management at the University of Queensland and hopes to pursue his career in this field.



Dr Torsten Witt, Research Fellow

Torsten is a polymer scientist from the School of Chemical Engineering, and has specialised in understanding the structure property-relations of biopolymers in a variety of multi-disciplinary and industry focussed projects. This has included understanding the role of biology and chemistry in the production of native ordered structures; the influence of biopolymer processing in altering food structure and food quality; and the chemical and physical modification of biopolymers to transform them into renewable biodegradable plastic materials. Torsten obtained his PhD in 2013 with the UQ School of Agriculture and Food Sciences. As a member of the Next-Generation Fertilisers project, Torsten is currently working on producing biodegradable slow release fertilizer to combat environmental nitrogen loss in the Great Barrier Reef catchment area.



Dr Songcan Wang, Research Fellow

Songcan Wang received his Bachelor of Engineering (2011) and Master of Engineering (2014) from Central South University, China. He was awarded his PhD degree in Chemical Engineering from the University of Queensland, Australia in 2018. During his Master, he was working on the development of functional nanomaterials for energy storage devices. During his PhD, his research focussed on the design of efficient photoelectrodes for solar fuel production. He joined the Dow Centre as a postdoctoral research fellow in May 2018, focusing on focusing on research in to the development of printed thin-film batteries.



Dr Rijing Lin, Research Assistant

Rijing obtained his Bachelor of Engineering and Master of Science from Sun Yat-sen University (China) in 2010 and 2012 respectively. He was awarded his PhD in Chemical Engineering from the University of Queensland in 2016. While completing his Master's degree, he was working on the functionalisation of polymers for CO₂ adsorption. During his PhD, his research focussed on the development of novel porous materials and fabrication of high selective mixed matrix membranes for gas separation and purification. Rijing started working at the Dow Centre as a Research Assistant in July 2017. He currently focuses on developing novel processes for hydrogen production without CO₂ emission via methane pyrolysis in molten metal system, and also works on the design of a new membrane reactor for primary methane pyrolysis.



Dr Andrew Pascale, Research Assistant

Andrew obtained a Bachelor of Arts in History and a Bachelor of Science in Electrical Engineering from the University of Notre Dame (USA) in 1998. He earned a Master of Science in Renewable Energy from Murdoch University in 2010. He was awarded his PhD in Chemical Engineering from UQ in 2018. In his Master's Thesis, he detailed the life-cycle assessment of a community scale hydropower system in rural Thailand - a project for which he had served as a project manager a few years earlier. In his PhD thesis, he refined standard presentations of energy use/carbon dioxide emissions and human welfare relationships to expose intra-country inequalities and allow compelling global challenges connected with the vision of a world characterized by universal High human development and minimal global warming, to be framed for individuals rather than nations. Andrew joined the Dow Centre as a casual Research Assistant in 2018, building knowledge and capability in tailoring and expanding the sectors and products contained in the MRIO data underlying the Rapid Switch CGE model.



Mr Jose Rehbein, Research Assistant

Jose is an Industrial Engineer from Universidad Adolfo Ibanez with a Master of Environmental Management from The University of Queensland. In his early career, he worked as an entrepreneur in the private sector, but also with the government and universities, developing renewable energy projects and strategic energy planning in Chile. He was awarded and directed seven grants from the Chilean Production Development Corporation, totalling more than US\$1 M, to develop storage technology, project design optimisation and business innovation for renewable energy. Following graduation from his Master's degree with the highest qualifications, he joined the Dow Centre as a Research Assistant, forming part of the core team working on the Rapid Switch project. His work focuses on spatial analyses for the optimisation of Carbon Capture and Storage (CCS) planning for the world, especially in critical regions such as India and China, building the most complete framework for studying the complexities for planning CCS at a global scale.

Dr Miaoqiang Lyu awarded Advance Queensland Fellowship

Dr Miaoqiang Lyu has been awarded a prestigious Advance Queensland Industry Research Fellowship (Early Career). Miaoqiang is part of the UQ team working with the Advanced Printing Technology for New Generation Flexible Printed Batteries CRC-P. Together with his UQ colleagues Professor Lianzhou Wang, Dr Jannie Grové, Dr Songcan Wang, Yuxiang Hu and Benoit Clement, Miaoqiang's research addresses the key fundamental and technical challenges in the development and printing of thin-film batteries.

The Fellowship – part of the Queensland Government's Advance Queensland initiative – aims to foster innovation and empower researchers such as Miaoqiang to translate innovative research ideas into commercial success and social benefits.

Miaoqiang will use this fellowship to investigate printable inks for low-cost, roll-to-roll printed thin-film batteries.

“My aim is to demonstrate self-powered electronic devices integrated by thin-film batteries, flexible photovoltaics and RFID (radio frequency identification device) as one potential application of these batteries”, Miaoqiang said.

This fellowship leverages the CRC project by extending its products in the Internet of Things (IoT) market. Applications include next generation flexible sensors, photovoltaics, medical devices, wearable/implantable electronics, paper-like displays, active Radio-frequency identification (RFID) devices and ultra-thin electronic skins based on highly stretchable organic transistors.

In most of these printed electronics, the flexible thin-film battery is an integral component with a predicted market of USD 1.72 billion by 2025 (Grand View Research, Inc.). The success of the printed thin-film batteries and IoT electronics will help Printed Energy Pty Ltd commercialise their products and provide a promising solution to low-cost IoT devices with the advanced manufacture technologies and thin-film batteries.

Our collaborative partnership with the Flexible Printed Batteries CRC-P aims to develop low-cost, printable batteries with potential to power evolving printed electronics such as sensors, Internet of things (IoT) devices, disposable healthcare devices, smart cards and other wearable electronics.





Dr Luigi Vandi

From Formula 1 racing to revolutionising the fertiliser industry, Luigi Vandi is driven by innovation for sustainable development.

Luigi Vandi has a diverse background in materials science, ranging from advanced manufacturing, in-life performance and end-of life conversion to higher value products.

Following completion of his Master of Science from the National Polytechnic Institute of Lorraine (France), Luigi joined the Ferrari Formula 1 Team (Italy) as a product engineer, where he was responsible for the manufacture, testing and certification of carbon fibre suspensions and gearbox of Ferrari's Formula 1 car. He has since developed a passion for composites and materials science innovations for sustainable development.

In 2009 Luigi moved to Australia and extended his industry experience with the CRC for Advanced Composite Structures (CRC-ACS), completing a PhD in novel technologies for the rapid assembly of composites with Airbus (France), significantly contributing to the field as he discovered a new chemical bonding mechanism giving rise to exceptionally strong interfaces. This led to two first-author patents and was further recognised as the winner at the annual Early Career Researchers Showcase presented by the CRC Association 2014.

At the Dow Centre, Luigi is developing novel sustainable materials based on biopolymers and biocomposites with a strong focus on translational research activities with

industry-relevant impact. One of his key projects looks at the development of biodegradable materials for next-generation controlled release fertilisers, aimed at reducing nitrogen losses to the environment, in collaboration with the Manildra Group, Queensland Government Department of Agriculture and Fisheries, and James Cook University.

Luigi is also involved in developing biobased composite materials from wood and a marine-degradable biopolymer called polyhydroxyalkanoate in collaboration with Norske Skog Paper Mills. In this project he also actively engaged with end users to explore new applications and progress their adoption.

Luigi is driven by making a difference to sustainable development and believes that materials science combined with education and industrially relevant research have a significant role to play.

The Dow Centre provides this ideal environment where important opportunities and barriers can be identified, and pursued in a manner that is most effective and relevant to industry.



Introducing Briony Beaumont, Centre Manager

The vast majority of us genuinely want to make a difference.

We are continually reminded of the scarcity, inequality, and risk faced by our society, both locally and globally, and feel compelled to do what we can to help. However, understanding the true nature of the problems we face and channelling our efforts toward their resolution presents a significant challenge.

Briony Beaumont started at the UQ Dow Centre as its Centre Manager in 2018. She believes that targeted research can effectively respond to this challenge, and shares the Centre's mission to identify, foster, and facilitate innovations in economically and environmentally sustainable processes.

"Drawing on the collective knowledge, passion and dedication of ambitious individuals can create truly remarkable outcomes for the betterment of society. Research Centres such as the Dow Centre at UQ provide an important meeting point for global challenges and the people dedicated to advancing positive outcomes, giving us good cause to be optimistic" Briony says.

"However as resources are always finite, we must be careful in how we approach these challenges in order to maximise our impact. As individuals, we can choose to take direct action in response to these challenges, donate to groups and organisations effective in their field, or support those that do."

The Dow Centre's focus on technologies and processes that are economically and socially viable, scalable, and that have the potential for a genuine and lasting impact, attracted Briony to the Dow Centre.

The ability to tell the story of shared experience and illuminate a path forward creates important dialogue and a space for collaboration. This is evident in many Dow Centre research projects.

"As the Centre Manager, it is a privilege to engage with dedicated and ambitious colleagues, students and donors, each determined to make a difference".

Briony herself is a UQ graduate, completing a Bachelor of Business Management at the St Lucia campus where the Dow Centre is located.

"Like many UQ graduates, I feel a great sense of responsibility to contribute to society and to the University that enabled me

to flourish. The time and effort that we invest over the course of our careers is not insignificant –this is one of the reasons that I am motivated to work for an organisation that is so intently focussed on creating positive impacts on people’s lives”.

“I was attracted to the Dow Centre because of its ability to do just that through research, teaching, and partnerships, where we have some of the brightest researchers and motivated students doing wonderful work every day”, she said.

New to the university sector in a professional capacity, Briony appreciates the enormous amount of ‘unseen’ effort, constantly occurring in the background, that enables vital research to continue with the pace and intensity that the UQ community is proud of. Professional and technical staff within the Faculty of Engineering, Architecture and Information Technology (EAIT) and UQ more broadly are helping bring about positive change by creating the world-class environment and systems relied upon by some the best researchers, teachers, and mentors in the field. Functions such as planning, information technology, finance, human resources, facilities, and communications are all critical resources to the University. To Briony, these functions are the mortar between the bricks (or sandstone) that comprise many of the more visible achievements at UQ.

In the first few months of her role at the Dow Centre, Briony was asked to organise the 2018 Sustainability Innovation Student Challenge Award (SISCA) competition. This competition provides an opportunity for students to collaborate with their peers across disciplines to make a positive impact on sustainability by applying the knowledge and skills gained from their study, and turn their bright ideas into reality. Entrepreneurship programs such as SISCA are not only an important part of the student experience at UQ, but invite students, staff, and members of the entrepreneurship and innovation community to apply their imaginations to the potential applications of engineering technologies in solving some of the world’s most pressing sustainability problems.

“It is truly heartening to see young people so thoroughly engaged in world issues, actively forging ideas and solutions, and honing their skills in the process. I was particularly encouraged by the rate of participation among our female students, who seized this opportunity and actively sought to address sustainability challenges through a combination of business and engineering skills, and a growing interest in entrepreneurship”, Briony said.

As we move into 2019, Briony is looking for ways to integrate the Dow Centre with the growing entrepreneurship and innovation ecosystem at UQ, in order to encourage and support a greater number of aspiring entrepreneurs.

As part of providing operational management of the Centre and supporting the delivery of the Centre and University’s strategic goals, she will also be looking to manage changes associated with streamlining of operations to support an agile, responsive and efficient operation, and ensure the effective implementation of improvement initiatives. After nearly a

decade working in governance and business-management roles, Briony is now completing a Master of Business Process Management to further explore her interest in the alignment of business operations, technology and organisational strategy.

As a member of the Dow Centre team, Briony also hopes to foster a collaborative and inclusive workplace culture that encourages the development of future academic and professional leaders.

“I look forward to advocating for the Dow Centre to promote its potential and the excellent outcomes being achieved by our researchers, collaborators, Advisory Board members, Centre leaders, and current and future students, toward a more sustainable and prosperous future”.

Drawing on the collective knowledge, passion and dedication of ambitious individuals can create truly remarkable outcomes for the betterment of society.



Centre HDR students



Mr Benoit Clement, PhD Candidate

Benoit is a PhD candidate at the school of Chemical Engineering, University of Queensland. He obtained his Bachelor degree in Chemical Engineering from the University of Queensland in 2013. After graduating, Benoit worked on several battery research projects in industry. He is experienced in the field of product development and has participated in the inception of a start-up company. His PhD project is investigating economical routes for manufacturing thin-film batteries en masse, intended for the market of small and flexible electronic devices. In October 2018, Benoit commenced as a member of the Flexible Printed Batteries CRC-P team at UQ, and is working to bring next-generation flexible printed batteries to the market.



Mr Mark Hodgson, PhD Candidate

Mark is a mature age PhD candidate sponsored by the Dow Centre. Mark's research explores methods to mitigate CO₂ emissions associated with production of cement. He contributes to University of Queensland teaching outcomes via tutoring activities. Previous formal education includes a Bachelor of Engineering (Chemical) and a Bachelor of Economics. He is a Fellow of the Institution of Chemical Engineers, and serves as the Australian committee member of the institute's Clean Energy Special Interest Group. Mark's working career included management of process performance benchmarking and improvement, optimisation, technology revamps, process safety, and technical auditing, within the oil and gas industry (both downstream and upstream). A career highlight was leadership of an international technical best practice working group for a major multi-national.



Mr Yuxiang Hu, PhD Candidate

Yuxiang received a Bachelor of Science degree from the School of Chemistry and Chemical Engineering at Nanjing University in 2012, and later obtained a Master's degree under the supervision of Prof. Jun Chen in the Key Laboratory of Advanced Energy Materials Chemistry (Ministry of Education, Nankai University). Yuxiang is currently a final-year PhD student studying under the supervision of Prof. Lianzhou Wang. Yuxiang is currently contributing to the Flexible Printed Batteries CRC-P, and hopes to continue his involvement in this project on completion of his PhD. His research currently focuses on nanomaterials, catalysis, metal-ion/oxygen batteries.



Ms Romy Listo, PhD Candidate

Romy is a graduate from The University of Queensland with qualifications in international development studies and community development. She has previously worked and volunteered in a range of community organisations and projects, including a micro-enterprise program with a focus on women's entrepreneurship and energy technologies in rural Guatemala. She has most recently worked in the field of relationships and sexuality education and prevention of violence against women in Australia, and continues to be active in this area. Romy joined the UQ Energy & Poverty Research group in January 2016. Her research explores how women are collective organising to improve their energy systems in rural India, and the impacts for women's empowerment. Romy is particularly interested in the gendered nature of energy poverty, and how changing social practices around energy systems and technologies can facilitate the transformation of gender relations.



Mr Yuwan Malakar, PhD Candidate

Yuwan is from Nepal and has an undergraduate degree in Environmental Management, and a Master of Sociology. He has over ten years of experience in the areas of poverty reduction, climate change, disaster risk reduction, humanitarian assistance, livelihood improvement, and natural resource management. Yuwan's PhD explores the underpinning social constructs of energy poverty in rural India and aims to generate lessons that have policy implications. Contributing to the Energy and Poverty Research Group and supported by the Dow Centre, Yuwan's research looks beyond infrastructural and economic bottlenecks and focuses on the role of social systems and their embedded socio-political arrangements that resist or enable a successful cooking fuel transition. A novelty of his research lies in the integration of two prominent theories, the Capability Approach and Structuration Theory, which provides a foundation to unfold the social affairs that impede the change process and their ensuing deprivation of human well-being.



Mr Gabriel Rioseco, PhD Candidate

Gabriel holds a Bachelor of Science and Master of Science in Industrial Engineering, with a specialisation in environmental economics from the University of Concepción, Chile. In 2018 he graduated from the University of Queensland with a Master of Sustainable Energy. In 2018, Gabriel joined the Dow Centre as a PhD student as part of the Rapid Switch project.

Gabriel's research focusses on the economics of energy systems, specifically determining the integration costs of variable renewables, and analysing their impact on the rate of deployment of renewables and broader macroeconomic variables.



Ms Sara Zeinal Zadeh, PhD Candidate

Sara obtained her Bachelor degree on Mechanical Engineering from the K.N.Toosi University of Technology in 2000, after which she worked in the oil and gas industry as project engineer and project manager in Persian Gulf mega projects. In 2012 she moved to Australia and in mid-2013 took up a one-year research project on Life Cycle Assessment of Solar Energy in Australia at the UQ Energy Initiative. After 12 challenging years dealing with fossil fuels and observing the real-in-site environmental impacts of conventional power generation technologies, she pursued a career change to contribute to contributing to improving the environment. Her PhD project involves solar energy technologies, solar policy and social impacts of solar deployment, and is part of the wider Rapid Switch project. Sara has been enhancing her skills in techno-political and techno-social modelling within the study. She is also involved with tutoring and mentoring of undergraduate students in engineering design and project management courses. Her aim is to become an academic in the clean energy space.

Research





The Dow Centre currently leads a number of research projects, which all aim to make original and significant contributions to global sustainability in the areas of production and utilisation of energy and materials.

When considering all research opportunities, the Dow Centre examines potential impact on global sustainability and our regional economy, as well as the potential for the Dow Centre to make a significant contribution.

Rapid Switch

*The global transition to a low carbon economy:
Understanding bottlenecks and constraints*

Global carbon emissions have been rising for more than a century, as a result of industrialisation-led growth and prosperity, based on fossil fuels. Now, a sharp and abrupt decrease in emissions is necessary to limit most adverse effects of anthropogenic climate change, while simultaneously enabling a more prosperous world through economic growth.

The Intergovernmental Panel on Climate Change, the International Energy Agency, and other institutions outline scenarios for a low-carbon transition. These reports all lack a critical piece – they do not speak to the pace at which decarbonisation could realistically occur given the state of technologies, and political, social, and economic constraints in various regions. Rapid Switch aims to fill this gap by rigorously analysing bottlenecks and unintended consequences that may arise during the transition, and resolving them sector-by-sector and region-by-region. By doing this in ways that respect local values and conditions, the project aims to identify the most viable and rapid transitions.

Rapid Switch will provide critical technology and region-specific insights to guide decision making by both policy makers and investors in this energy transition.

Some of the key questions that guide this framework include:

- » How do viable approaches for decarbonisation differ between advanced and developing countries?
- » How can incumbent and new-entrant energy companies be incentivised to accelerate this transition?
- » How can critical industrial bottlenecks that could slow transitions be anticipated and resolved, in advance?
- » How can the socio-economic impacts of stranded assets be minimised?
- » How can international alliances accelerate outcomes?

This approach uniquely grounds cross-disciplinary framing of bottlenecks with local stakeholder engagement. Linking macroeconomy-energy-emissions modelling with analyses of industrial, socio-political, and fiscal systems will inform regional priorities for technology innovation, investment capital, human resource development, and initiatives to effect social change.

Anticipating and resolving system bottlenecks will be critical to sustain the kind of rapid decarbonisation of the global economy consistent with the objectives of the Paris Agreement, i.e. net-zero emissions by the second half of this century. Insights from Rapid Switch can help to both guide the early



decarbonisation investment priorities and more realistic longer term energy transitions that recognize national economic and development agendas within the context of global climate mitigation ambition.

The project has built significant momentum through 2018. In July, Centre Director Chris Greig commenced his role at Princeton University as the Andlinger Visiting Fellow in Energy and Environment, mission to expand and align the international Rapid Switch network, advancing the research agenda and accelerate fundraising efforts.

In the last year, the research team expanded to include several leading academics at Princeton University, spanning a variety of disciplines including welfare economics, political science, energy systems, ecology, civil and environmental engineering, policy, and psychology..

Progress in 2018 has focussed on:

- » Raising the international profile of the Rapid Switch;
- » Ranking Low-Carbon Transitions in terms of vulnerability to bottlenecks; and
- » Exploring decarbonisation transition challenges faced by developing economies.

These efforts have laid the groundwork for cross-disciplinary programs of research focussed on energy transitions in the USA and India, which will formally commence in 2019.

In the year ahead, we plan to escalate research efforts in India and initiate research in China while consolidating programs in Australia and the USA.

Transition challenges for very high VRE penetration in electricity grids.

This work seeks to identify the various technological, economic and socio-political challenges associated with very high levels of variable renewable electricity (VRE) in electricity networks.

The research has three elements:

1. VRE representation in CGE models

This work, led by Stephen Wilson (UQ), seeks to develop improved characterisation of system costs and performance of integrating high shares of variable renewable energy generation in national and regional electricity systems for use in computational general equilibrium modelling of economy-energy-emissions.

Most models currently use traditional levelised cost of electricity measures and fail to fully account various integration

costs. This work will develop better representation of costs such as:

- » Balancing costs associated with the limited predictability of VRE, which causes intraday forecast errors. This requires short term balancing and reserve capacity;
- » Grid costs associated with installation and upgrade of transmission lines to connect new VRE capacity, often be located in remotes areas; and
- » Profile costs associated with the inherent variability of VRE and the temporal mismatch between VRE generation and electricity demand. Such costs include backup generation investment, reduced utilisation of dispatchable generation and VRE curtailment.

2. Power systems grid modelling and optimisation

This work, led by Princeton, has two components:

- » Grid Modelling:

This work seeks to explore the challenges associated with near-term operational, long-term capacity expansion and portfolio optimisation challenges and opportunities associated with very high VRE penetration using a proprietary grid modelling software, Aurora. This work is focusing initially on a single case study being the PJM Interconnector, the largest competitive wholesale electricity market in the USA and the world's second largest after the European Integrated Energy Market; and

- » Electricity market design

This work uses a specially developed Electricity Market Simulation Tool to design and test intriguing new market design concepts which incentivise investment and minimize consumer costs. Products include various locational, marginal pricing approaches for energy, as well as capacity, ramping and fast-start features.

3. Decision-making bottlenecks in low carbon electricity transitions

This work, led by Princeton, will examine socio-political and behavioural bottlenecks associated with key elements of low-carbon electricity transitions. The work will consider such bottlenecks for a spectrum of stakeholders including investors, regulators, consumers and special-interest groups. Two case studies will be explored, relevant to the north-east USA:

- » High voltage transmission and energy storage; and
- » Off-shore wind generation.



Rapid Switch India

Of the major greenhouse gas (GHG) emitting regions in the world, India presently has the lowest GDP per capita and lowest energy use per capita. However by mid-century, India is projected to be the most populous nation with an economy expected to be comparable in scale to China. India's projected economic growth will require a huge increase in energy use — approximately 30% of the global increase over the next 40 years. In response to these unique challenges, the Rapid Switch India research program is primarily concerned with India's transition from coal to solar while trying to achieve rapid economic growth and poverty alleviation. The high-level research questions being investigated in collaboration with Princeton¹, IIT-Bombay and IIT-Delhi include:

1. What are plausible scenarios for long-term energy demand growth in India?
2. How can India maximize the rate of low-carbon (dominated by solar) electricity deployment?
3. What are the economic, social and political implications associated with a rapid transition from a coal-based to a renewables-based energy economy in India?
4. What political bottlenecks, or rapid-flow channels might emerge in a transition from coal to renewable energy?
5. How might political, socio-economic, and psychological forces dynamically interact to create complementarities, barriers to change, and/or path dependencies in the transition from a coal-based to a renewables-based energy economy?

Rapid Switch USA

The USA provides a very different context, as the world's richest nation, well-endowed with energy infrastructure and resources. This motivated a project² to explore whether a major low-carbon infrastructure plan to decarbonise the US economy by mid-century could present a viable physical and economic proposition. The plan will be defined spatially and temporally at the major project level which will be unique in such national decarbonisation studies. The approach sets out to minimize execution bottlenecks, rather than optimise the asset portfolio, and considers only technology choices that are available today - i.e. technologies that have been demonstrated at industrial scale.

The research team will build industrially informed schedules and cost estimates for development, permitting and construction activities. This will involve developing narratives that describe the necessary policy, financial, industrial, human and social characteristics that will be necessary for such scenarios to commence and be sustained.

Several scenarios will be analysed including:

- » Electricity sector decarbonisation with various mixes of renewables (40% and 80% VRE; nuclear (high and low); and coal or natural gas with carbon capture and storage (CCS) (high and low);
- » Electrification of all light duty vehicles and rail;
- » Hydrogen fuel cells (HFC) and biofuels for long haul road transport;
- » Biofuels for shipping and aviation;
- » Electrification, hydrogen and CCS in industrial processing;
- » Electrification of space heating;
- » Robust contribution from agriculture and forestry uptake in all scenarios; and
- » Residual emissions off-set with negative emissions technologies such as Bioenergy with CCS (BECCS) and/or Direct Air Capture with CCS (DACCS).





Rapid Switch will provide critical technology and region-specific insights to guide decision making by both policy makers and investors in this energy transition

Emerging projects

A variety of smaller and/or emerging projects are being explored, all of which have the potential to increase in profile in coming years. Emerging research areas include studies on:

- » Bottlenecks in expanding the production and use of alternative low-GHG cements, with studies ongoing at both UQ and Princeton; and
- » Increasing tensions between:
 - businesses and states in Australia that benefit from fossil energy exports;
 - their international customers, and;
 - domestic climate action policies (including medium-term (2030) state-based targets for renewable energy levels, which are among the world's most ambitious); and
 - the potential for this tension to influence fossil fuel exports.

Key people: UQ: Chris Greig, Stephen Wilson (Mechanical Engineering), Karen Hussey (Centre for Policy Futures), Simon Smart, Dr Joe Lane (Princeton based from February 2019), Andrew Pascale (Princeton based from January 2019), Martin Stringer, Mark Hodgson, Sara Zeinal Zadeh, Gabriel Rioseco, Eve McDonald-Madden (School of Earth and Environmental sciences), Belinda Wade (UQ Business School) and Jacquelyn Humphrey (UQ Business School).

Princeton: Marc Fleurbaey, Robert Keohane (Emeritus), Atul Kohli, Eric Larson, Simon Levin, Denise Mauzerall, Michael Oppenheimer, Stephen Pacala, Robert Socolow (Emeritus), Elke Weber, Ali Daerarpour, Tom Kreutz, and Chai Molina.

Carnegie Melon: Mitchell Small, Gabrielle Wong Parodi, Turner Cotterman

Tsinghua University: Li Zheng, Chongqing Kang, Ma Linwei

IIT-Bombay: Rangan Banerjee

IIT Delhi: Ambuj Sagar



1. Princeton's participation is funded by the Princeton Institute for International and Regional Studies (PIIRS).

2. Princeton's participation is funded by BP and ExxonMobil.

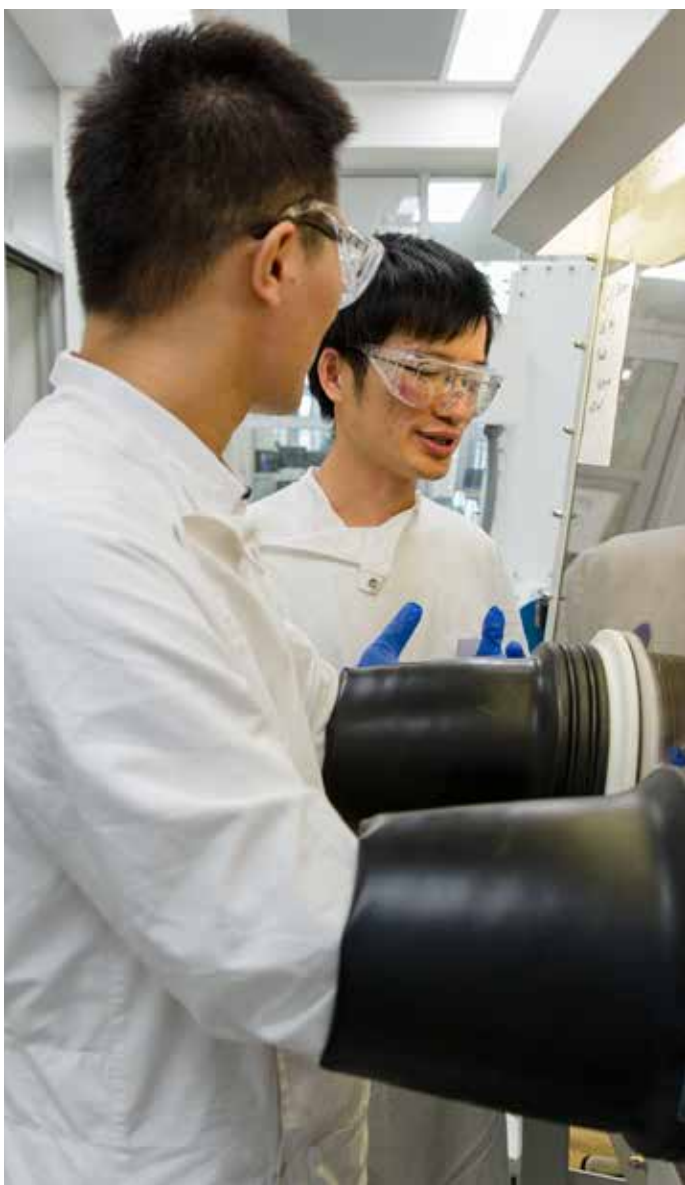
Flexible Printed Batteries CRC-P

In 2017, the UQ Dow Centre, the Wang group within AIBN, the School of Chemical Engineering, and researchers from the University of New South Wales (UNSW) were successful in securing a Cooperative Research Centres Projects (CRC-P) Grant, led by Printed Energy Pty Ltd. The Flexible Printed Batteries CRC-P creates a three-year partnership between leading-edge researchers and industry to design, build and market flexible, ultra-thin printed batteries.

These flexible printed batteries are printed in a roll-to-roll process, similar to a newspaper, and can be packaged as stand-alone products, or as integrated components for other products. This approach will bypass traditional battery technologies by providing a physically flexible battery that can be made with very inexpensive materials in virtually any format, using a high speed, inexpensive manufacturing process.

This unique printing process allows these flexible batteries to be adapted to almost any shape or product, creating a range of applications limited only by the imagination. This may include Internet-of-Things devices, wearable sensors and electronics, disposable medical devices and smart cards, to industrial scale solar energy storage. This presents a real opportunity for the next generation of Australian manufacturing to take advantage of cutting edge technology and innovation.

The UQ Dow Centre has been instrumental in defining an engagement model that works for both industry and academia. The commercialisation plan provides clear direction for the research and a sense of urgency to solve the substantial technical challenges.



Key people: Lianzhou Wang, Chris Greig,
Jannie Grové, Miaoqiang Lyu, Songcan Wang,
Yuxiang Hu, Benoit Clement



The Flexible Printed Batteries CRC-P team formally commenced work in July 2018, and initially focussed efforts on:

- » the establishment of several research facilities;
- » characterisation of battery materials; and
- » devising methodologies to analyse raw materials, electrolytes and printable separators.

Since commencing, the team has made significant progress in fundamental lab-scale research, having characterised the physiochemistry of the batteries, identified a suitable sealant for the batteries, and completed robustness and performance testing of prototype primary and secondary batteries.

This early success has enabled the team to successfully demonstrate medium-scale ink production, scale-up of battery production to small-to-medium scale, successfully integrate printed LEDs and RFIDs with batteries at a proof of concept level, and to submit of a patent application.

In parallel, Printed Energy Pty Ltd worked on developing scale-up processes for some of the key findings made by the University teams and completed successful pilot tests of smart wearable devices using the printed batteries through a collaboration with a pilot partner.

The Dow Centre is proud to work alongside the Wang group within AIBN, UNSW and Printed Energy Pty Ltd to translate research in to real-world solutions.

Printed Energy is supported by Trevor St Baker, AO, an energy innovator, philanthropist, and founder of ERM Power and the St Baker Energy Innovation Fund.

Rodger Whitby, CEO of the St Baker Energy Innovation Fund plays a key role in leading the project as the Chair of the Printed Energy CRC-P Advisory Board.

“Printed Energy is very excited to be collaborating with the UQ Dow Centre on a CRC-P project to develop thin flexible batteries using roll-to-roll printing techniques. A whole new class of electrochemical inks is being developed and applied to traditional printing processes”, Mr Whitby said.

“By pooling our resources, knowledge and insights in a collaborative framework, industry and academia are achieving great progress in the field of thin flexible batteries.”

Next-Generation Fertilisers

A collaboration between the Dow Centre, School of Chemical Engineering, School of Agriculture and Food Sciences, the Queensland Department of Agriculture and Fisheries, James Cook University and the Manildra Group aims to dramatically reduce excess fertiliser run-off, which has negative impacts on land degradation, water quality, and the health of delicate ecosystems such as the Great Barrier Reef.

Modern agriculture relies on mineral fertilisers to replace the main essential nutrients (nitrogen, phosphorous, and potassium) removed with the harvest product. Approximately 50 % of the nutrients from conventional mineral fertilisers (being water-soluble salts) are released into the atmosphere, nearby waterways, or groundwater. As a result, plants often only absorb half of the nutrients from fertilisers. This is particularly true where a crop is in its early stages, and cannot absorb the nutrients quickly. In addition, some existing slow-release fertilisers contain non-degradable plastics, contaminating soil with micro-plastics long after the fertiliser has been applied.

These insights suggest that modern fertilisers are far from efficient or environmentally sustainable. The resulting environmental impacts are evident in agricultural settings throughout the world.

In response to this challenge, the Dow Centre is aiming to improve the efficiency of fertiliser use and reduce negative environmental impacts using material science, applications design and microbiology. Over the last year, Dow Centre researchers have focussed on the development of a new type of fully-biodegradable material that slows the release of nutrients such as urea (a nitrogen containing compound, used as a cost-effective source of fertiliser for crops) in to soil. To do so, Dow Centre researchers are developing pellets (spherical or cylindrical shaped granules) based on starch and/or other biopolymers (also known as bioplastics).

Since receiving an Advance Queensland Innovation Partnership (AQIP) Grant in 2017, the project has advanced to assess both the release of urea from pellets, as well as the degradation of the pellets in soil.

The Dow Centre aims to improve the efficiency of fertiliser use and reduce negative environmental impacts using material science, applications design and microbiology.



In the initial phase of nutrient-release trials, a range of pellet materials were screened to determine release rates of urea in water, now being followed by more accurate laboratory trials using new soil/sand release tests that more closely mimic field and pot trial conditions, prior to undertaking large-scale field trials. Trials then progressed to lab-based pot trials of plant growth and health using a selection of the screened pellets.

In parallel, trials were undertaken to ascertain whether the pellets leave any residue in the soil. A study of the degradation of pellets over a period of 6 months also commenced to ensure that new materials are truly biodegradable and do not leave any contaminants.

Researchers found that the use of polyhydroxyalkanoates (PHAs) in the pellet delivered the expected release profile comparable to commercial products. However, importantly, these pellets did so without the harmful effects of soil contamination. PHA performance was deemed to be optimal, however following a cash-flow margin analysis of different materials the volume of PHA necessary was found to be comparatively too costly, and required that a more cost-effective material be investigated. PHA has subsequently been used as a benchmark to assess the release profile of subsequent material trials. This research also found that wheat starch on its own is ineffective at slowing the release sufficiently, leading the team to assess a wheat starch/urea/clay composite in the pot.

In the second phase of release trials, clay structures were introduced to trap the urea within the starch or PHA bioplastic. To date, trials indicate that the clay can successfully trap the urea, however this structure now needs to be combined

with bioplastic or starch in a successful manner in order to effectively release the urea. It is intended that once further refined, this structure will provide more consistent control over the release of fertiliser in to the soil.

Additional material development is also now underway using a broader range of biopolymers and sorbents along with coating materials designed to slow the uptake of water.

In September 2018, the AQIP Report for Milestone 3 of the Fertiliser Project was submitted to the Queensland Government, and initial research results presented to the Dow Centre Advisory Board in October.

Planning for field trials has now been completed. While field trials will be undertaken on sugarcane crops, this research could be adapted to any crop grown in Australia such as rice, non-food and sorghum. Commencing in 2019, researchers will be undertaking a 12 month field trial in North Queensland in order to test improved formulations for more efficient nutrient release.

Key people: Bronwyn Laycock, Steven Pratt, Susanne Schmidt, Damien Batstone, Paul Luckman, Luigi Vandi, Torsten Witt, Nicole Robinson



Fight Food Waste CRC

Food waste is costing Australia an estimated \$20 billion each and every year, and is directly affecting Australia's food industry efficiency and reputation as a clean and green food producer. Food waste is also a global issue, with losses valued at \$1.6 trillion per year. Much of the developed world is now committed to the United Nations Sustainable Development Goal 12.3: By 2030, halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including postharvest losses.

In November 2017 Australia committed to this goal through the National Food Waste Strategy. The best way of achieving this goal is through turning 'waste' in to a resource through adopting circular bio-economy principles. To secure Australia's food future, the Fight Food Waste CRC will reduce food waste throughout the supply chain, transform unavoidable waste into innovative high-value coproducts and engage with industry and consumers to deliver behavioural change.

The CRC comprises three key activities or programs, each underpinned by a platform of food safety and security. These include:

Program 1: Reduce (Reducing Supply Chain Losses), focussed on:

- » Mapping resource flows, waste and root cause analysis;
- » Reviewing functions and consumer perceptions of packaging and processing;
- » Investigating product specific supply chains and identify opportunities; and
- » Investigating methods to increase food donation and measure its social impact.

Program 2: Transform (Transforming Waste Resources), focussed on:

- » Identifying and prioritising valuable products from waste streams;
- » Identifying technology gaps and process limitations in waste transformation;
- » Delivering a tool kit for optimising technology and feedstock combination choice; and
- » Evaluating socio-economic impact of alternative policy settings
- » Conducting techno-economic assessments of alternative processes

Program 3: Engage (Education and Behavioural Change), focussed on:

- » Educating future industry professionals;
- » Disseminating industry and skills training; and
- » Developing household and business behaviour change instruments.

Key people: Bronwyn Laycock, Paul Luckman, Joe Lane, Noni Creasey

A/Prof Bronwyn Laycock led Program 2, the largest program within the bid with a budget of \$45.451M. From 1 January 2019 the role of Program Leader will transition to Dr Paul Luckman to lead the Transform Program within the FFW-CRC. Scope exists for additional projects to arise from this work, through collaboration with the Queensland Government's Department of Agriculture and Fisheries and other research partners around Australia, particularly in the area of techno-economic evaluation.

Research Report

While the CRC is yet to commence formal research activities, significant progress has been made throughout 2018 in the development of the research program, preparation of bid documents, hosting of workshops, coordination of research activities, managing industry engagement as well as exploring new research opportunities for the CRC.

2019 will see Commencement of Research Program 2 and progression toward a number of key milestones, including:

- » The establishment of the program coordinator role within the CRC;
- » Coordination and review of project proposals, and provision of oversight;
- » Establishment of the SME solutions centre funded by FIAL through the CRC and likewise provide oversight of same;
- » Expansion of networks and relationships for ongoing research activities; and
- » Exploration of new partnering opportunities.



Low-CO₂ Production of Iron

Iron and steel production is the largest energy consuming industry in the world and one of the largest CO₂ emitting industries producing around 5% of the world's greenhouse gas emissions.

The main focus of decarbonisation scenarios for the iron and steel sector is carbon capture and storage (CCS) at an estimated cost of between \$70 and \$120 per tonne of CO₂, assuming suitable geological resources to store CO₂ are available. Arguably three of the top four steel producing countries (China, Japan and India) do not have suitable geology, bringing CO₂ reduction strategies into question. Direct reduction with hydrogen or electrolysis technologies for iron production with a high share of renewable energy are not economically attractive without a very high CO₂ price.

This project seeks to use new chemistry to explore lower cost decarbonisation pathways. The original approach was a unique process to co-produce iron and organic chemicals utilizing natural gas without direct CO₂ emission through a chemical looping concept. In this scheme, reduction of iron ore and natural gas conversion were facilitated by a molten salt mixture and electrolysis. Due to process complexity, that process has been shelved in favour of a simpler scheme that focuses on iron production, with a solid carbon by-product.

Research Report

The new process for low CO₂ iron production first takes iron ore and converts it to iron chlorides using hydrochloric acid (HCl) gas. Water is driven off at high temperatures as the iron chlorides become molten. The molten salt mixture is reduced to iron by using methane and / or hydrogen in a bubble column reactor. Iron and solid carbon are formed and separated from the molten salt mixture. HCl gas is formed as a by-product, which is then recycled to beginning of the process to convert

fresh iron ore to iron chloride. The morphology, and therefore value, of the solid carbon product is variable. There is strong evidence from the methane pyrolysis work, however, that the morphology can be controlled to produce desirable carbon by-products of significant value.

The process flowsheet has been developed into a full techno-economic model for preliminary cost estimation of an industrial scale iron production plant. The findings indicate that the molten salt technology proposed here always outperforms traditional blast furnace technology with CCS and can be economically competitive with blast furnace technology with low to moderate natural gas prices. The solid carbon by-product has relatively minor impact on process economics.

The focus for 2018 has been in the laboratory, specifically on the reactions that produce solid iron. Two approaches were taken, both utilising molten salts. In the first instance iron ore (mixtures of Fe₂O₃ and Fe₃O₄) was suspended in inert molten salts and passed methane or hydrogen through the molten mixture in a bubble column reactor. The iron oxides were reduced but particle agglomeration was a serious issue, clogging the reactor and reducing conversion. Several different molten salt eutectics were trialled to reduce the agglomeration to limited success. As this process offered no benefit over existing direct reduced iron schemes, further experimental work has been put on hold.

The second set of experiments focussed on converting the iron chloride salts to iron. Here the focus was on hydrogen as a reducing gas to simplify the reaction chemistry. Extensive investigations found that the reaction happens predominately in the gas phase and thus conversion is determined by the vapour pressure of the iron chlorides in the molten salt. Equilibrium conversion was reached even with very short residence times which suggests the reaction kinetics are very fast. Future work for the coming year will focus more on confirming and quantifying the fundamental chemistry. The gas phase reaction also necessitates a reactor redesign before redoing the techno-economic analysis.

*Key people: Simon Smart, Chris Greig,
Eric McFarland, Howard Fong, Khuong Vuong,
Mojgan Tabatabaei, Taiwo Odedairo,
Rijia Lin*



Methane pyrolysis for hydrogen production

Development of an innovative and sustainable technology to utilise methane for hydrogen production as both a chemical feedstock and a clean source of energy, is a priority research area for the Dow Centre.

Methane pyrolysis using molten metals and molten salts is a promising alternative pathway for hydrogen production without CO₂ emissions. Initial techno-economic analysis of an industrial scale hydrogen plant demonstrates that the molten metal technology always outperforms electrolysis and steam methane reforming with carbon capture and storage (SMR+CCS) as low CO₂ routes to hydrogen. Furthermore, it even outperforms traditional unabated SMR at a carbon price exceeding \$21 per tonne CO₂. The analysis shows that the hydrogen production via methane pyrolysis is sensitive to both energy and separation costs. In order to reduce hydrogen production costs we are working on a one pot pyrolysis solution with in-situ carbon removal and hydrogen separation using the membrane reactor concept. This will reduce equipment costs, energy input and remove the need for downstream hydrogen purification. In particular, certain molten metals have good hydrogen solubility and diffusivity which allows us to design a reactor where the metal will work as both a catalyst and separation media.

Research Report

The pyrolysis of methane is a direct and commercially attractive process to produce H₂ without CO₂. Downstream separation and purification of H₂ from the unreacted methane

is most frequently performed using pressure-swing adsorption (PSA) with a high efficiency at low temperature. An alternative option is to use the molten metal catalyst as a membrane for high temperature H₂ separation. The concept of using a liquid metal membrane is almost entirely unique and it has never been applied with methane pyrolysis before. All the literature focuses on using thin metallic films of palladium-based alloys in reforming, gasification or water-gas-shift reactors. The excessive cost and limited chemical and mechanical stability have hindered the industrial applicability. However, H₂ solubility and diffusivity in liquid metal alloys is much higher, allowing cheaper and more stable metal alloys to be used.

Building on the initial investigations in 2017 a Sieverts apparatus was designed and built for testing hydrogen solubility and diffusivity in molten metals. This allows characterisation of the molten metal alloys for hydrogen transportation and provides a way to screen metal and metal alloys using hydrogen separation properties.

Building a membrane reactor using a thin film of liquid metal has proven much more challenging. Initial designs utilised bubbling columns of molten metal suspended over a porous ceramic frit. However, the diffusion distance was too great to get appreciable hydrogen flux at low operating pressures required for safety. Efforts are being made to reduce the thickness of the membrane but it is difficult to achieve due to the poor wettability between the metal and the porous silica or alumina support.

In response the system was modelled to determine the potential of the membrane reactor concept, to both improve conversion and determine the amount of membrane area required to replace the PSA system. That work continues into 2019, with promising modelling results indicating minimal residence times are required at high pressures to achieve the desired H₂ flux.

The work on the conventional production of hydrogen via methane pyrolysis in molten metal and salt systems continues under the Future Fuels CRC. 2019 will see investigations into ternary metal mixtures for improved catalytic activity and a variety of molten salt eutectics for improved carbon removal.

Key people: Simon Smart, Chris Greig, Eric McFarland, Howard Fong, Rijia Lin, Mojgan Tabatabaei, Taiwo Odedairo, Khuong Vuong



Future Fuels CRC

The Future Fuels Cooperative Research Centre (Future Fuels CRC) seeks to enable the transition of Australia's electricity, transport, agriculture, mining, construction and industrial sectors to the use of clean fuels, through the use of more sustainable materials such as hydrogen, biogas and liquid derivatives like ammonia and methanol, as well as through the adaptation of existing gas infrastructure for the production, transport, storage of gas.

Incorporated in 2018, the Future Fuels CRC has been established to help the Australian gas and pipeline industry provide a competitive, low carbon energy alternative for residential, commercial, industrial and transport sectors to complement and support intermittent renewable electricity generation.

The Future Fuels CRC will develop solutions for current infrastructure and equipment to use low carbon fuels today and well into the future through the pursuit of three core research programs:

- » Future Fuel Technologies, Systems and Markets – which seeks to provide a thorough understanding of the technical, commercial and market barriers to, and opportunities for, the use of future fuels.
- » Social Acceptance, Public Safety and Security of Supply – studying the social and policy context, including public acceptance and safety, for technology and infrastructure associated with future fuels.
- » Network Life Cycle Management – focussed on the design new cost effective integrity systems to enhance operations of the infrastructure carrying both existing and future fuels.

The Future Fuels CRC presents an exciting opportunity for the Dow Centre to contribute to Program 1, commencing 2019.

Over a two-year project the Dow Centre will undertake techno-economic modelling of fuel production processes, drawing on the expertise of the Centre's techno-economic analysis capability. Outputs will include process models and designs, techno-economic models, breakeven production cost analysis for a commercial plant and a basic engineering design for a pilot-scale field demonstration plant.

A second three year project building on flagship research into molten metal methane pyrolysis work will also commence in 2019. That project will employ a Research Fellow and support two PhD students.

*Key people: Simon Smart, Chris Greig,
Mojgan Tabatabaei*

Low-CO₂ production of Cement

The global cement industry accounts for approximately 7% of overall Greenhouse Gas (GHG) emissions. Cement production is at around 4.2 billion tonnes per annum (tpa). This is a 25% increase over predictions made a decade ago, and can be largely attributed to increased cement production in China. The World Bank predicts that ongoing population growth and increasing urbanisation will lead to continuing strong demand for cement.

The International Energy Agency (IEA) 2°C Scenario (2DS) involves the capture and sequestration of 740 million tpa of CO₂ from cement production by 2060. A more aggressive scenario targets 1800 million tpa. Carbon Capture and Storage (CCS) adds around 100% - 150% to the supply cost of cement. The first pilot test of cement industry CO₂ CCS is scheduled for 2020 (subject to funding approval), which lags IEA expectations.

Research report

This research examined process options designed to avoid a significant portion of CO₂ emissions. Attention was directed to process adjustments leading to improved thermal efficiency and reduced fuel consumption. The reference point for process energy consumption and economics is that which would otherwise be devoted to CCS.

In 2018, preliminary experiments were carried out with calcium carbonate to test the concept of reacting the CO₂ liberated from the calcination of calcium carbonate with methane to produce a H₂ rich syngas. Initial testing confirms that reasonable products can be produced at a reaction temperature of ~8000°C. This would be especially attractive to industry where the majority of dry reforming attempts produce a syngas with high CO content, which ultimately results in high CO₂ emissions. Further to the experimental work a predictive model of gas-phase reactions has been completed and is being used to understand the benefits of combining cement and syngas production. Such a tool has application for both calcium and magnesium systems, and will assist the design of future experimental work in 2019.

To aid this work, the locations of the world's cement plants have been mapped and researchers are working with the Rapid Switch team to understand the layout of CO₂ storage reserves. The team also analysed the regional cement industries and are comparing against best practise. This will provide an understanding of how the regions compare on an energy and CO₂ emission intensity basis, highlighting the gap between worldwide best practice and the CO₂ targets for the cement industry. From this the team will develop an understanding of the global implications of adding CCS to cement production on a regional basis which considers both feedstock, energy, CCS and product transport costs. This will be the first picture of how CCS would impact the global cement industry and whether the paradigm of building cement plants near limestone reserves continues in a carbon constrained world. Further work in 2019 will compare this base case against our proposed co-production process to establish which regions would be most suitable for deployment.

Key people: Simon Smart, Chris Greig, Mojgan Tabatabaei, Mark Hodgson

Dry reforming of natural gas in molten metal and salt systems

This project departs from the typical Dow Centre perspective on CO₂ emissions – using innovative chemistry and process routes to avoid the production of CO₂ – and instead focusses on how to use innovative chemistry to utilise CO₂ with natural gas to produce syngas.

Dry reforming (DR) has long been investigated as a viable pathway for the conversion of methane to chemicals with the added benefit of CO₂ utilisation. However, traditional dry reforming technologies have been plagued by catalyst sintering, stability and coking. Likewise, alternative production through utilising plasmas or electrochemistry are yet to demonstrate economic viability, much less comparable economics to other forms of methane utilisation.

The Dow Centre is using catalytic molten metal and molten salt systems to improve the current DR technologies, to enhance overall efficiency and ultimately prevent catalyst deactivation. In particular the molten state of the system means that coke production is no longer a problem as any carbon produced simply floats on top of the melt and can be removed. Indeed, carbon production can be encouraged, through feeding excess methane into the reactor, as it is accompanied by increased hydrogen production. This enables DR to produce high value syngas with H₂:CO ratios in excess of two and has the potential to unlock natural gas fields with high CO₂ content, and presents an alternative option to CCS where natural gas is available.

In a simplified process, the raw natural gas from the reservoir is preheated and routed to the molten reactor after desulfurisation of natural gas. The dry reforming reaction between methane and CO₂ occurs in a molten media in the presence of a suitable catalyst. The produced syngas is sent to the downstream unit for further processing and excess carbon is floated to the surface of the molten media in the reactor to be skimmed off and sent to a downstream unit for further separation. The novel system shows the possibility of producing a higher H₂:CO ratio in compare with the current DR technologies which can directly be used for the production of value-added chemicals/fuels with continuous carbon removal. In theory any syngas ratio >1 can be produced simply by feeding excess methane. The extra hydrogen production will be accompanied by an increase in solid carbon by-product and enabling complete utilisation of the CO₂.

Research Report

This work has progressed on two fronts in 2018. In the first instance the team developed a detailed process model for the dry reforming of natural gas into methanol. Using a natural gas feedstock high in CO₂, the team tested whether the process would be suitable to either a) add value to an existing LNG operation (i.e. in place of carbon capture and storage) or b) direct conversion of the raw natural gas into a higher value liquid product. Both options were economically feasible with a low to moderate CO₂ price, although the second option was the more economically attractive of the two. The study identified that finding a suitable supply of high temperature, low carbon, low cost heat to drive the endothermic reactions was critical for the economic and environmental success of the project. Current renewable technologies suffer from technical limitations which mean they cannot supply heat at the required temperatures. Natural gas on the other hand is very capable of supplying the required heat, but doing so reduces the overall CO₂ utilisation to 1/3 of its potential if carbon free heat was used. The team will continue to explore low carbon options in collaboration with our partners in the Future Fuels CRC.

Experimentally, the team have been intensively working on a new concept for production of syngas via dry reforming of methane without losing the catalytic activity of the catalyst. The new system utilizes a heterogeneous catalyst (e.g. Fe/Al₂O₃) in a molten salt for syngas production, where the CO₂ activation occurs mostly on the heterogeneous catalysts and the CH₄ cracking predominantly takes place within the molten salt. Preliminary tests confirm that the catalytic activity of the catalysts can be maintained well beyond the lifetime of conventional dry reforming catalysts. In 2019 the team will extend the salt systems under investigation and incorporate learnings from the methane pyrolysis project to enhance methane conversion to generate the desired H₂:CO ratio. The team anticipate much of that work will be conducted as part of the Future Fuels CRC.



Key people: Simon Smart, Chris Greig, Eric McFarland, Howard Fong, Khuong Vuong, Mojgan Tabatabaei, Taiwo Odedairo, Rijing Lin



Techno-economic Analyses

Underpinning the Dow Centre's approach to research is a commitment to only pursue projects which have the potential to have significant impact on global sustainability. Techno-economic analysis (TEA) plays an important role in determining which processes and projects are economically competitive and scalable as well as environmentally and socially acceptable.

TEA combines process modelling and engineering design together with economic evaluation, and involves developing and applying advanced quantitative methods for techno-economic, life-cycle, and sustainability analyses to new processes and opportunities for sustainable production and use of energy and materials. It helps to assess the economic viability of a technical process and provides direction to further research, development, investment, and policy making.

As a key component of the Dow Centre's research and consulting projects throughout 2018, Techno-economic Analyst Mojgan Tabatabaei has undertaken a number of TEAs for Dow Centre projects, UQ projects, and on behalf of industry clients. A short summary of those is as follows:

Conversion of waste to fuel

The Dow Centre developed a first-order Process Model, TEA and Life Cycle Assessment (LCA) of an innovative process to convert biomass and landfill wastes to a drop-in diesel product at a capacity of 3000 litres per hour. The study was delivered under a research services agreement as part of a CRC-Projects grant with EcoFuel Innovations (EFI). For the base scenario, utilising shredded woody waste, the Centre's analysis found:

- » Waste-wood to diesel technology was potentially viable under certain conditions.
- » The cost of production of diesel is especially sensitive to capital cost, electricity cost and feedstock credit.
- » High Australian manufacturing costs are not viable even at high feedstock credit values and plant should be procured as preassembled modules manufactured in China.
- » Several risks and uncertainties must be addressed in the current proposal, particularly in relation to feedstock impurities, diesel quality and proprietary equipment performance.



Modelling for a novel electrochemical separation process

The Dow Centre developed a generic process model for a continuous multi-stage electrochemical separation process and perform a TEA based on single stage data provided by the client, including concentrations and enrichments of feed and receiving streams, cell current and voltage, membrane area and electrode spacing, and cell volume. The process was found to be economically feasible and the team identified opportunities for process improvement.

Separation of magnesium from lithium containing brines

The Dow Centre was engaged by an industry partner to analyse the potential of a novel process for separating magnesium from lithium containing brines with the potential to replace the conventional evaporation / crystallisation approach for lithium carbonate production. The preliminary investigation of the technology included the development of a process model based on a batch process and using experimental data. An initial TEA followed industry protocols with Association for the Advancement of Cost Engineering (ACEE) Class 5 capital and operating cost estimates.

Overall, the process model and techno-economic analysis demonstrated a compelling case for the continued development of the process beyond the lab scale.

Dry reforming of CO₂ rich natural gas in a molten media

Transforming of CO₂ and CH₄ into valuable products through dry reforming process is a promising pathway to reduce our global carbon footprint. The Dow Centre investigated a novel process to convert low quality natural gas with high CO₂ content to a commodity chemical such as methanol via synthesis gas. A process model was developed in Aspen Plus for dry reforming in molten salts based on experimental results. A preliminary TEA showed that chemical production has economic merit, however this innovative process is energy intensive, and a significant CO₂ price is needed in order to compete with the conventional synthesis gas processing. Further investigation is underway to address major key challenges.

Key people: Mojgan Tabatabaei, Simon Smart

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YEAR IN REVIEW
Engagement

The Dow Chemical Company

The cutting-edge research being undertaken at the Dow Centre would not be possible without the longstanding support of the Dow Chemical Company.

The Dow Chemical Company's US\$10 M investment in the Dow Centre has underpinned our contributions to research and education since 2014. Dow extended their commitment to the Centre in 2018 with a further gift of US\$3.5 M (\$4.4 M).

President Dow Asia Pacific, Jim McIlvenny, visited the Dow Centre at UQ in July this year.

"The Dow Centre has become a hub of excellence for collaborative research across diverse fields, generating potential solutions to some of the biggest issues facing society." Mr McIlvenny said.

In 2018, Dow's generous support was boosted by a \$6 M endowment of the Dow Chair in Sustainable Engineering Innovation, securing the Dow Centre's ongoing capacity to deliver leading research and innovation in sustainable production of energy and materials.





Engagement

PHILANTHROPIC ENGAGEMENT

The support of donors helps further our objective to deliver solutions to globally significant challenges by generating new knowledge.

INDUSTRY ENGAGEMENT

The Dow Centre focuses on current industry challenges and contribute to the sustainability of industrial processes through its collaborative projects.

ACADEMIC ENGAGEMENT

Our academic networks include universities in the USA, Europe and Asia. We regularly publish with international researchers and collaborate closely with our UQ colleagues.

COMMUNITY ENGAGEMENT

Engagement and collaboration with diverse communities strengthens research outcomes and improves the relationship between research institutes and society.

GOVERNMENT ENGAGEMENT

The Centre seeks to contribute to national and international policy-making through its capacity to deliver systems analysis and its focus on scalable, solution-focussed research projects.



PHILANTHROPY

Recognising the St Baker Family

Trevor and Judith St Baker have been long-standing supporters of the University and their community, spearheading multiple investment and philanthropic initiatives that build breakthrough technologies in the fields of energy, transport, and healthcare.

Their stunning generosity was recognised in 2018, when The Trevor and Judith St Baker Family Foundation donated \$1.5 M to establish the prestigious Tritium Visiting Fellowship in Electro-Mobility (e-Mobility) at the UQ Dow Centre.

Recognising the potential for Australia to transition to a more sustainable transport industry, Trevor and Judith St Baker are supporting research, development and technological leadership that will advance the electrification of the transport sector.

TREVOR AND JUDITH ST BAKER

Mr St Baker and his wife Judith are proud to support an initiative that will promote international collaboration and growth in a sustainable energy industry in Australia.

Mr St Baker's longstanding commitment to research and investments which advance sustainability was recognised in 2016, when he was appointed an Officer of the Order Of Australia (AO). Following a 50-year long career in the energy sector, Mr St Baker is the founder and a director the St Baker Energy Innovation Fund, which invests in a portfolio of companies that develop disruptive products across the energy sector and supports clean energy initiatives spanning generation to consumption, and including innovations that enable entirely new products, performance improvements of existing products, increased efficiency and more sustainable processes. In 2017, Mr St Baker also joined the Board of the University's *Not If, When* philanthropic campaign which aims to raise \$500 M for priority projects by the end of 2020.

TRITIUM

The Tritium Fellowship is affiliated with Tritium, a Brisbane-based leader in e-mobility and manufacturer of electric vehicle chargers and part of the St Baker Energy Innovation Fund portfolio. Tritium, founded by three UQ alumni, provides world-leading fast charging systems designed to support the global transition to e-mobility for clean, healthy and convenient cities globally. Through the rapid expansion of its electric vehicle (EV) charging network in Australia, Europe and the USA, Tritium has already made significant steps toward the electrification of transport globally. Their flagship product (the Tritium Veefil 50kW) is the only liquid-cooled fast charger on the market today. Manufactured locally in Brisbane, Tritium is committed to providing opportunities for a wide-range of professionals to develop technologies for the uptake of e-mobility.

THE TRITIUM FELLOWSHIP IN E-MOBILITY

The St Bakers' historic gift to establish the Tritium Visiting Fellowship in e-Mobility will bring world-leading experts to UQ to lead research activities directed toward advancing the performance, economics and uptake of e-Mobility globally. From mid-2019, the inaugural Tritium Fellow will join a community of researchers and academics connected with the UQ Dow Centre undertaking research across a range of disciplines, focussed toward advancing sustainability in the production and use of energy and materials on a global scale. The Tritium Fellowship will support a research agenda and lead activities to enable and accelerate the expansion of electric vehicle use and other forms of electric mobility globally. Research undertaken by Tritium Fellows will make an important contribution to informing public policy, investment decisions, technology innovation, public health studies and community behaviour in support of the transition to sustainable, low-emission, electric-powered transportation. This

research aligns with the Rapid Switch Project, a global research collaboration co-led by UQ and Princeton University that aims to increase our understanding of bottlenecks that could slow the rate of decarbonisation, and ultimately inform priorities for technology innovation, capital investment, social change initiatives, and policies aimed at accelerating climate change mitigation. Fellows will have the opportunity to investigate and address a variety of issues such as design of improved electric vehicle charging systems, the role of electric vehicle batteries in providing electricity storage for grid management, the design of policies and incentives to accelerate electric vehicle uptake. A truly multidisciplinary research area, this research may extend to urban planning and infrastructure design to accommodate high penetration of electric vehicles, social and behavioural studies in relation to electric vehicle uptake, life cycle analysis of electric mobility benefits, or analysis of co-benefits of electric mobility such as air pollution. The Fellow will also contribute their expertise to the UQ community through involvement in course coordination, lecturing, and supervision of PhD students.

The Tritium Fellow is an exemplar of what is possible through partnerships between research, industry and philanthropy. The gift will enable the Dow Centre to support the global knowledge economy in the transport sector, and draw on expertise across the fields of engineering, economics, behavioural science, public

health, and other related disciplines. UQ Vice-Chancellor and President Professor Peter Høj said the partnership exemplified the cross-disciplinary nature of the green technology research that UQ is involved in alongside our partners in education, industry and philanthropy.

This vision is shared by Rodger Whitby, CEO of the St Baker Energy Innovation Fund. An experienced senior executive with 30 years of experience in the international energy sector, Rodger understands the integral role of philanthropic support and targeted investments in creating and scaling innovations that create positive outcomes for society.

“Increasingly we live in a world of convergence. There is no better example than the e-Mobility space” said Rodger.

“Electric vehicle uptake in Europe and America has been growing steadily and is approaching a tipping point, at the same time as ride sharing and autonomous vehicles are revolutionising the transport sector. There is growing choice of EV models and a rapidly emerging public and household roll-out of EV charging infrastructure.

But the electric vehicle is a battery on wheels, so there are wide reaching implications for the energy sector as well.

There is an opportunity to do something positive for the environment by replacing gasoline with renewable power generation as the predominant transport fuel. The fleet of batteries can also be used as a widely distributed

energy storage device, which could be used to manage the intermittency of the renewable energy generation, for grid stability, and even dampening some of the price volatility in electricity wholesale markets.

The management and co-ordination of EV battery charging and discharge at a household level is all made possible by wireless comms, the roll-out of an IOT data spectrum and cloud based analytics.

The ramifications are widespread. There will be impacts on public health, jobs and skills, infrastructure projects, transport economics, vehicle design, business models and even the way electricity is sold.

The social and technology changes need to be discussed, debated, improved and optimised. What better platform for such debate and knowledge sharing than a university based fellowship?

The St Baker Family Trust and the St Baker Energy Innovation Fund is proud to sponsor the Tritium Visiting Fellowship in e-Mobility at UQ, and we look forward to participating in the public discussion this exciting initiative will generate.”

The Dow Centre and UQ are thankful to the St Bakers who are helping to drive renewable energy initiatives that advance a more sustainable and prosperous world. Together we can create this change – ‘Not If, When’.



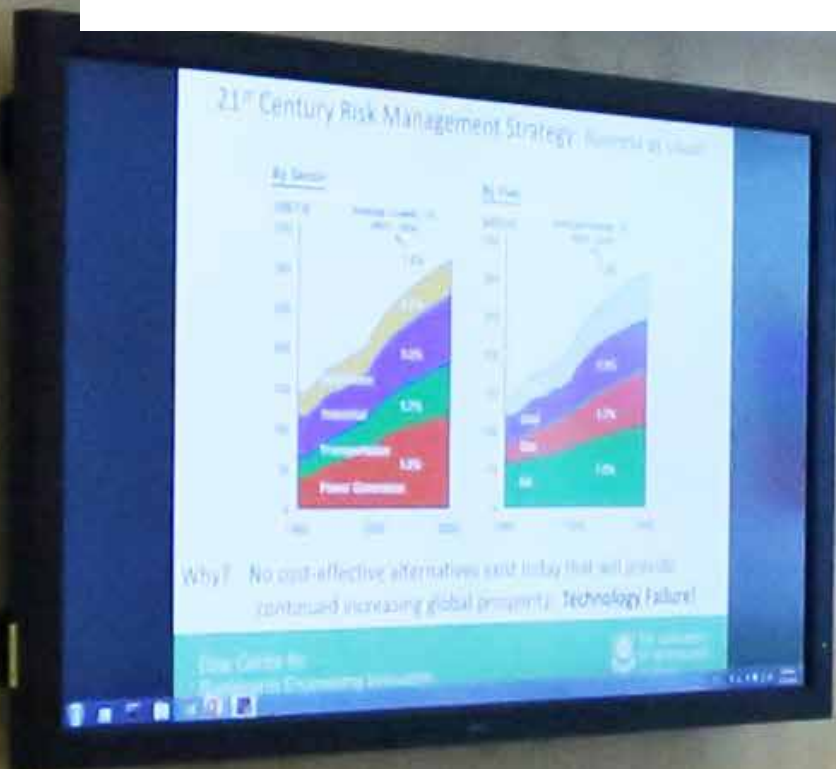
Industry

Throughout 2018 the Dow Centre continued to strengthen its relationships with industry partners through the provision of specialist consulting services and formal partnership schemes, including the Advance Queensland Innovation Partnerships (AQIP) program and the Cooperative Research Centres (CRC) Program. The Centre remains committed to projects that focus on current industry challenges and contribute to the sustainability of industrial processes.

With the support of the AQIP program – a program dedicated to backing collaborative research projects with end-users – the Dow Centre has partnered with industry on the Next-Generation Fertilisers project. This project aspires to develop environmentally responsive fertilisers, strengthening Brisbane's position as a global innovation hub and gateway into industry and international markets.

The CRC Program is an Australian grant scheme designed to promote research and collaboration between research bodies and industry. Through this scheme, the Dow Centre is able to address current industry challenges and contribute to improved competitiveness, productivity and sustainability of Australian industries.

In 2018, our researchers also worked closely with Printed Energy Pty Ltd. following the successful establishment of the *CRC-P for the Development Of Ultra-Thin, Flexible Screen-Printed Batteries*, led by Printed Energy Pty Ltd.



INDUSTRY

Partnering with Printed Energy

Printed Energy is very excited to be collaborating with the UQ Dow Centre on a CRC-P project to develop thin flexible batteries using roll-to-roll printing techniques. Through this partnership, a whole new class of electrochemical inks is being developed and applied to traditional printing processes.

Mr Rodger Whitby, CEO of the St Baker Energy Innovation Fund and Chair of the Printed Energy CRC Advisory Board (pictured below) believes that effective university-industry partnerships are key to creating change.

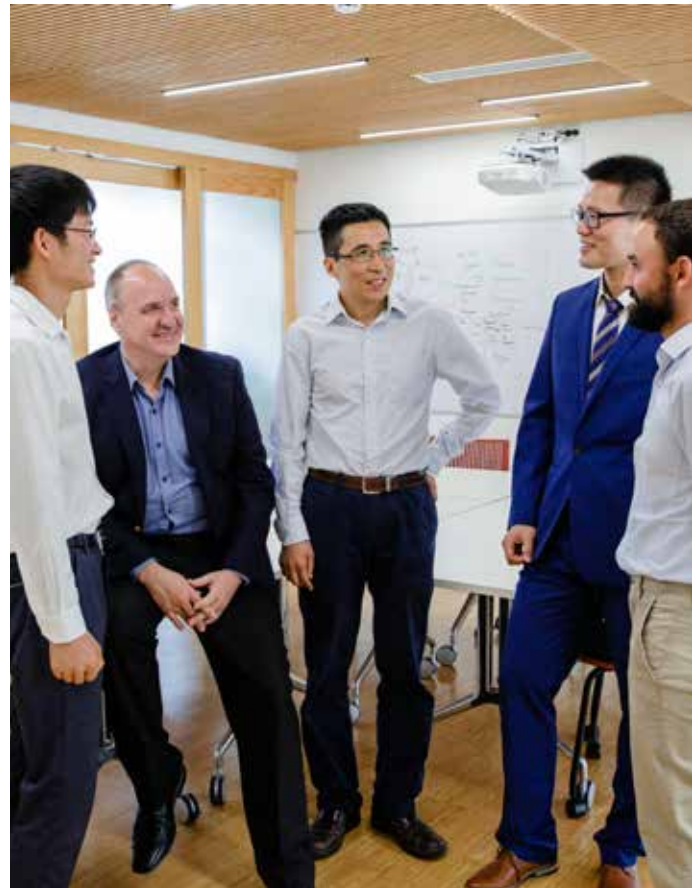
“The Dow Centre is playing a key role for the project which brings together UQ, UNSW, Printed Energy and two other industry partners to bring existing technology concepts to market,” said Roger.

“The project is focused on better understanding and optimising the electrochemical performance of the batteries, developing fully printable protective packaging for the batteries and fully integrating the printed batteries with other printed electrical components to make functioning devices. The universities have a wealth of equipment and talent to apply to the challenges. The project's aim is to make it possible to manufacture products such as smart labels, thin flexible medical devices, wearable electronics, light weight disposable sensors, active IoT devices and many more exciting products.”

“The UQ Dow Centre has been instrumental in defining a collaboration model that works for both industry and academia. The core IP originated with Printed Energy and all project IP will stay with Printed Energy – because they are best positioned to generate value from the IP through commercialisation. In return, the universities receive revenue for the research activities and royalties from future profits. The commercialisation plan provides clear direction for the research and a sense of urgency to solve the substantial technical challenges.”

“By pooling our resources, knowledge and insights in a collaborative framework, industry and academia are achieving great progress in the field of thin flexible batteries.”

Members of the UQ Flexible Printed Batteries CRC-P team



Partnering with Princeton University

Collaboration with leading academic institutions in Australia and internationally plays an important role in our mission to make a meaningful and widespread impact through research.



Lynn Loo, Director of the Andlinger Center for Energy and the Environment at Princeton University

The Dow Centre is proud to partner with world-leading institutions to advance our research agenda and create change.

The Rapid Switch Project is an exemplar of effective academic collaboration.

Originating at the UQ Dow Centre, the Rapid Switch Project has made significant progress in 2018 through the engagement of the Princeton University and broader Rapid Switch community.

While based at Princeton as the 2018 Gerhard R. Andlinger Visiting Fellow in Energy and the Environment, Professor Chris Greig has been able to further strengthen these relationships.

Yueh-lin (Lynn) Loo, is the Director of the Andlinger Center for Energy and the Environment and Professor of Chemical and Biological Engineering at Princeton University.

“The mission of the Andlinger Center for Energy and the Environment at Princeton University is to develop solutions to ensure our energy and environmental future. This

endeavour requires the involvement of a diversity of actors and stakeholders, including a global body of researchers. The centre is thrilled to have Chris Greig as a Gerhard R. Andlinger Visiting Fellow and, through Chris, establish a strong partnership with the University of Queensland. In the short time since joining the centre, Chris’ real-world experience on carbon capture and sequestration and global perspective on energy systems, have greatly diversified the community, enriched existing research initiatives, and spawned new projects at the Andlinger Center.” Lynn Loo said.

“The Andlinger Center is proud to partner with the Dow Centre for Sustainable Engineering Innovation at the University of Queensland to jointly spearhead a multi-national and multi-institutional study on decarbonisation, known as Rapid Switch. Rapid Switch seeks to answer the question of how quickly global decarbonisation could realistically occur given the state of technologies, and regional political, social, and economic constraints.”

“The research is uniquely grounded in macroeconomy-energy-emissions modelling with analyses of industrial, socio-political, and fiscal systems, and local stakeholder engagement. Different from the many existing scenarios that outline a low-carbon transition, Rapid Switch specifically speaks to the pace of decarbonisation. By critically analyzing bottlenecks and unintended consequences that may arise during the transition, resolving them sector-by-sector and region-by-region, and respecting local values and conditions, this collaboration will identify the most viable, rapid transition pathways.”

“In its first year, Rapid Switch has already facilitated a substantial exchange of knowledge between Princeton and the University of Queensland through student and postdoctoral research exchanges. The centre is excited for the partnership between Princeton and the University of Queensland to continue to diffuse expertise across continents, taking meaningful steps toward creating integrated and effective strategies for global decarbonisation.”

“The Dow Centre’s knowledge and leadership, in combination with the deep and diverse expertise and research strengths of the Andlinger Center and larger Princeton University community, will collectively yield positive outcomes for long-term global energy and environmental management.”



"The Dow Centre is proud to partner with world-leading institutions such as the Andlinger Centre at Princeton University, to advance our research agenda and create real change."



Chris Greig at the Andlinger Centre, Princeton University

Energy and Poverty Research Group

Engagement and collaboration with diverse communities strengthens research outcomes, improves the relationship between research institutes and society, and reinforces the vision of almost every scientific endeavour, that is, to improve lives while protecting the environment. The Energy and Poverty Research Group (EPRG) – a collaborative program including a range of schools across UQ – seeks to address the challenge of providing affordable, reliable and sustainable energy services to the energy impoverished – exemplifies this sentiment.



Vigya Sharma (pictured with Yuwan Malakar, Nicole Penman, and Romy Listo) and the EPRG team work directly with governments at all levels and community organisations to establish reference sites to demonstrate the link between sustainable energy and improved social, health, environment and livelihood outcomes.

The Dow Centre is a proud sponsor and partner of the group, and continues to support their efforts to improve social, environmental and health outcomes that are vital for sustainable and productive livelihoods in energy impoverished communities in the developing world.

Modern, clean and efficient energy services are crucial for human wellbeing. They facilitate social and economic development, bring shared prosperity, and foster equity and gender empowerment. EPRG's work has the potential to drive changes that will improve and even save the lives of millions of people around the world, while also delivering many environmental benefits.

EPRG currently has 12 projects already underway in India with plans to expand further.

“We work across all scales, from small villages with less than one hundred people, to a project mapping more than 160 countries,” says EPRG Program Leader Professor Paul Lant.

While predominantly focussed on the energy challenges in rural India, the EPRG have built a wide network of collaborators across Nepal, Cambodia, Myanmar, Papua New Guinea and Southern Africa, comprising academic, think tanks, and private sector organisations.

EPRG also partners closely with local academic and community groups in India including the Foundation for Ecological Security, IIT-Bombay, Tata Institute for Social Sciences, Ashoka Trust for Research in Ecology and the Environment, TERI, Practical Action,



Xavier Institute of Management, and Yuva Vikas. Closer to home, the EPRG also works closely with Monash University, CSIRO, Solar Buddy and the Kokoda Track Foundation within Australia.

Through EPRG, PhD student Yuwan Malakar spent time engaging with communities in rural villages in India to investigate the barriers that prevent the uptake of clean energy sources, collecting data, and speaking with both men and women in the villages. In 2018, EPRG built on the knowledge gained through Yuwan's research to better understand the underpinning social constructs behind the uptake of modern, clean energy sources in rural villages.

In late 2018, Postdoctoral Research

*“Our vision is to support the United Nation’s goal to alleviate energy poverty through achieving universal access to affordable, reliable and sustainable energy services by 2030”,
Professor Paul Lant*



Fellow Dr Vigya Sharma undertook focus group discussions and interviews with members of the community in Odisha, India to draw on the collective experiences and knowledge of community representatives, civil servants, and members of the public to understand the socio-economic dependencies of the coal sector and the potential for those resistances to slow national decarbonisation ambitions. EPRG researchers such as Vigya and Yuwan regularly work directly with governments at all levels and community organisations to establish reference sites to demonstrate the link between sustainable energy and improved social, health, environment and livelihood outcomes.

2018 included many more highlights for the EPRG; a number of PhD students were awarded a grant from French energy company Total to organise a training exercise on energy literacy in Papua New Guinea. In addition, two PhD students from partner institutions in India

were awarded a fully-paid scholarship to visit the EPRG for three months to work on a collaborative project as part of their current research. By hosting visiting students from India, EPRG was able to further strengthen its collaborative partnerships in 2018.

“Our vision is to support the United Nation’s goal to alleviate energy poverty through achieving universal access to affordable, reliable and sustainable energy services by 2030”, Professor Lant said.

“Moving forward, we hope to partner with key players in governments and the private sector to maximise our impact and expand our work to the rest of India and the world.”

There are great opportunities for government and private sector partners to build on these existing collaborations. Expressions of interest to partner with the EPRG are welcome, either through project-specific funding, in-kind support or as part of the EPRG’s wider consortium.

GOVERNMENT

Contributing expertise

Dow Centre researchers are regularly called upon to share their expert knowledge and research developments with domestic and international media.

In 2018, Dow Centre leaders were recognised for their leadership in engineering, climate change, and plastics.

Simon Smart became the Energy Sector Expert for the Queensland Government’s Climate Adaptation Strategy Sector Adaptation Plan for the manufacturing, mining, energy and supporting industries.

Bronwyn Laycock was invited to chair the expert science panel advising the Queensland Government Department of Environment and Science on the forthcoming Plastic Pollution Reduction Plan.

Chris Greig made a number of contributions through his role as a Fellow of the Academy of Technological Sciences and Engineering, including New Membership Committee, Clunies Ross Innovation Awards, and government briefings. Chris also Chaired the Energy Policy Institute of Australia (EPIA).

Stephen Wilson succeeded Chris Greig as a Director of the EPIA in July, and was also involved in a number of State and Federal Government briefings.

YEAR IN REVIEW

Student experience

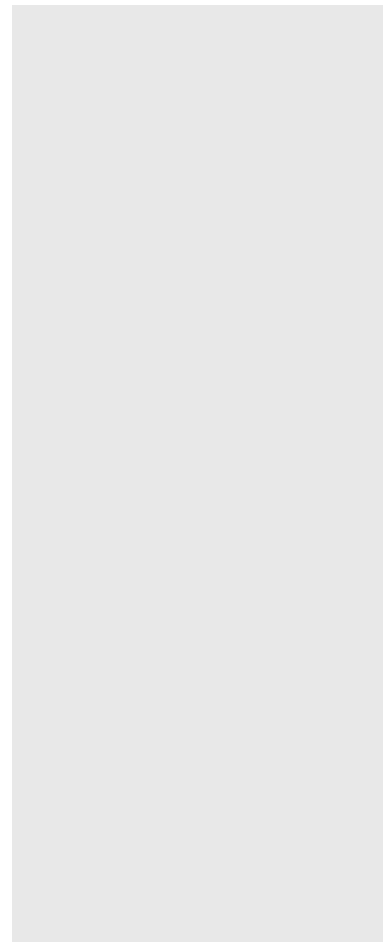
The Dow Centre values the perspective that our industry partners bring to the teaching and learning experience of our students. In 2018, three accomplished industry guests shared their insights with our eager engineering students.

Dow Centre Director Chris Greig welcomed Mr Jim McIlvenny, President of Dow Asia Pacific as a guest lecturer in ENGG4900. Students were able to learn first-hand from Mr McIlvenny's long and successful career in industry, gaining insights in to the management of megaprojects, innovation and the future of sustainability.

Redback Technologies Founder and CEO Mr Phil Livingston also shared his experience as a successful entrepreneur, speaking on innovation in the electricity sector and the challenges and opportunities of entrepreneurship.

Dr David Miller (Chair of Princeton University's Faith in Work Initiative) led an 'Ethics in Business' panel discussion with Mark Hutchinson (former GE Europe President) and Chris Greig for ENGG4900 and ENGG701.

Acknowledging the importance of cross-disciplinary teaching and collaboration, Dow Centre leaders also delivered numerous guest lectures within other UQ courses throughout 2018.



Students



TEACHING AND LEARNING

The Dow Centre seeks to build capacity among young engineers to develop more sustainable systems in this an ever-changing environment. The Dow Centre's approach to teaching and supervision aims to encourage fresh ideas and that support young innovators.

HIGHER DEGREES BY RESEARCH

Students who join the Dow Centre to undertake higher degree study and research have access academic leaders with experience that encompasses industry and research, and the foresight to seek solutions that support sustainable innovation.

SUSTAINABILITY INNOVATION STUDENT CHALLENGE AWARD (SISCA)

Through the Dow Centre's annual SISCA competition, students are invited to submit innovative ideas with a tangible engineering focus that address global sustainability issues through the production and use of energy and materials.

STUDENT SUCCESS

The Dow Centre fosters the next generation of thinkers - future research, industry and government leaders that have the capacity to understand and address the significant challenges to the sustainability of our planet.

A man with a mustache, wearing a white short-sleeved button-down shirt, stands behind a light-colored podium in a lecture hall. He is looking towards the audience. In the foreground, the backs of several students' heads and shoulders are visible, showing they are seated at desks. The room has a white wall and a green chalkboard in the background.

STUDENT EXPERIENCE

Teaching and learning

A key element of the Dow Centre's purpose is to equip a new generation of thinkers to tackle the complex issues in rapidly changing social, political and physical environments.

These challenges range from the need to transition to low-carbon production, community acceptance risks, regulatory change and geopolitical change.

As it is no longer adequate for engineers to work alone in their technical disciplines, the Dow Centre seeks to build capacity among young engineers to develop a multi-disciplinary approach to problem-solving.

The Dow Centre's approach to teaching and supervision aims to encourage fresh ideas and that support innovators with solutions to the major challenges in the production and use of energy and materials.

Students who join the Dow Centre to undertake higher degree study and research have access to leaders with experience that encompasses industry and research, and the foresight to seek solutions that support sustainable innovation.

Dow Centre researchers contribute their expertise to the teaching curriculum at UQ, through course-coordination, lecturing, tutoring and mentoring in 13 courses (see next page).

In addition, the Dow Centre hosted, the Dow Centre hosted a number of undergraduate students undertaking ENGG1600 "Introduction to Research Practices - The Big Issues" in Semester 2, which introduces students to the world of research through a 10-hour placement in a research centre that is reflective of their interests. Through this program, students were invited to participate in Dow Centre team meetings and engage with our researchers to gain a firmer understanding of the nature of research, and why it is essential to ensuring a sustainable and prosperous future.

UNDERGRADUATE AND POSTGRADUATE COURSEWORK

- » **CHEE2010 Engineering Investigation and Statistical Analysis**
Dow Centre contributors: A/Prof Bronwyn Laycock (Course Coordinator and Lecturer) and Dr Luigi Vandi (Lecturer).
- » **CHEE3301 Polymer Engineering**
Dow Centre contributors: A/Prof Bronwyn Laycock (Course Coordinator and Lecturer)
- » **CHEE4001 Process Engineering Design Project**
Dow Centre contributors: Dr Jannie Grové (Tutor) and Mark Hodgson (Tutor)
- » **CHEE7103 Chemical Engineering ME Design Project**
Dow Centre contributors: Mojgan Tabatabaei (Lecturer)
- » **ENGG1200 Engineering Modelling and Problem Solving**
Dow Centre contributors: Sara Zeinal Zadeh (Group Leader)
- » **ENGG4900 Professional Practice and the Business Environment**
Dow Centre contributors: Prof Chris Greig (Course Coordinator and Lecturer, Semester 1), Prof Stephen Wilson (Course Coordinator and Lecturer, Semester 2), Dr Jannie Grové (Co-lecturer and Tutor), Mark Hodgson (Tutor)
- » **ENGG7601 Experimental Design (Postgraduate)**
Dow Centre contributors: Sara Zeinal Zadeh (Tutor)
- » **ENGG7901 Professional Practice and the Business Environment**
Dow Centre contributors: Prof Stephen Wilson (Course Coordinator and Lecturer) and Prof Chris Greig (Lecturer).
- » **ENGG7902 Engineering Innovation and Leadership**
Dow Centre contributors: A/Prof Simon Smart (Course Coordinator and Lecturer)
- » **ENGY4000 Energy Systems**
Dow Centre contributors: A/Prof Simon Smart (Course Coordinator and Lecturer)
- » **ENGY7000 Energy Systems and Renewable Energy**
Dow Centre contributors: A/Prof Simon Smart (Course Coordinator and Lecturer)
- » **ENGY7004 Energy Sector Investment and Finance**
Dow Centre contributors: Prof Chris Greig (Course Coordinator and Lecturer), Dr Jannie Grové (Co-lecturer and Tutor),
- » **ENGY7117 Energy Markets Law and Policy, MES Intensive**
Dow Centre contributors: Prof Stephen Wilson (Lecturer).



STUDENT EXPERIENCE

Higher Degree Research

The Dow Centre offers opportunities for PhD students to benefit from UQ's world-class facilities at the St Lucia Campus, as well as undertake research more broadly in Australia and globally, engaging with academic institutions, NGOs, and local communities. In 2018, Dow Centre leaders supervised 67 students undertaking PhD, MPhil, and undergraduate thesis programs through the University of Queensland and collaborating institutions.

Of these, 16 students directly contributed to Dow Centre projects, including the Rapid Switch Project, Next-Generation Fertilisers, and the Flexible Printed Batteries CRC-P. A further 26 pursued research related to these projects, contributing to the fields of materials science, chemical engineering, and sustainability.

The Dow Centre's global perspective is reflected and encouraged in the research of its HDR students. Turner Cotterman and Romy Listo each had the opportunity to collaborate with leading academics and communities internationally to gain a broader perspective and inform their research.

Turner Cotterman is a PhD candidate in the Engineering and Public Policy Program at Carnegie Mellon University in the USA, co-supervised by the Dow Centre's Professor Stephen Wilson, and Carnegie Mellon's Professor Mitch Small. As a Visiting Scholar at the Dow Centre, Turner focussed on assessing the rates and extent of decarbonisation activities by linking macroeconomic modelling with project planning and approval processes. Turner's research is part of the larger Rapid Switch project, focussed on integrating socio-economic bottlenecks into global economy-energy-emissions (Integrated Assessment) models.

Following his visiting scholarship at the Dow Centre, Turner will return to Carnegie Mellon University in the USA to finish his PhD.

The Rapid Switch project (led by the University of Queensland) involves established collaboration with Carnegie Mellon University and Princeton University in the USA, strengthening Australian-US co-operation in an important area of research.

In 2018, PhD Candidate **Romy Listo** travelled to South Africa to deepen her knowledge of energy, gender equality and women's empowerment. During her field work Romy spent three months in Cape Town, and a further three months in Johannesburg working with members of the Lavender Hill community, 'Project90by2030' in Cape Town, and the Women's Energy and Climate Change Forum of Earthlife Africa, as well as a number of different women's cooperatives and enterprises supported by the Green Business College in Johannesburg. In 2018, Romy drew on the insights gained from her community-focused research to publish two academic research articles and submitted her PhD thesis, *Power to empower? Exploring the role of energy in women's organising and empowerment in rural India*.

Since returning to Australia, Romy was awarded the Madeleine Taylor Scholarship by the School of Social Science and invited to present her research at an NGO forum in New York running parallel to the UN Commission on the Status of Women in March 2019.



STUDENT EXPERIENCE

UQ Summer Research Program

The UQ Summer Research Program provides UQ students with an opportunity to gain research experience working alongside some of the university's leading academics and researchers. In 2018, the Dow Centre hosted four undergraduate students as part of the UQ Summer Research Program between mid-November and mid-February. These students worked alongside Dow Centre researchers to learn valuable academic and professional skills, gain an insight in to the field of professional research, and contribute to research outcomes at the Dow Centre.

Stephanie Lim is a 3rd year Chemical and Biological Engineering student. In the late November 2018, she participated in a ten-week summer research program under the supervision of A/Prof Simon Smart at the Dow Centre. Her project involved modelling the methane pyrolysis reaction with a liquid metal membrane reactor, a proposed CO₂-free technology with the potential for high-yield hydrogen production. She is particularly interested in clean energy production and is hoping that her summer research experience could be a learning opportunity for her to explore the different opportunities available for a possible career in the energy industry.

"It is very exciting for me to have the opportunity to be alongside very passionate people at the Dow Centre. For that ten weeks during summer, I learnt from everyone that if you do what you love, you will never work a day in your life and I too would like to be in a career that I could regard as something I 'love' to do and not something I 'need' to do."

"My experience at the Dow Centre has been wonderful. It is very exciting and enjoyable to work alongside very passionate people here and it has definitely encouraged me to search for what I am passionate about and to keep learning."

Mark Mcconnachie joined the Dow Centre working as an undergraduate research assistant with a summer research scholarship in 2018. He worked on furthering a previous project to develop a low emissions magnesium production pathway through process coupling.

Mark is currently studying a dual degree of Chemical Engineering and Art History at UQ.

Mark's unorthodox study pathway has lead him to Nepal with Engineers Without Borders Australia, UQ's Student Energy Network, and as an art teacher outside of university. His interests are in climate change and human centred design and he hopes that after graduation in July 2019, he will be able to continue working in these areas.

Mojgan Tabatabaei mentored Stephanie and Mark while at the Dow Centre.

Mojgan said, "this program was a great way for our students to gain research experience and explore both scientific and industry applications in chemical engineering".



STUDENT EXPERIENCE

Current centre students

Student whose research forms part of a Dow Centre project

* Student whose research is related to Dow Centre projects. Many of these below to the Energy and Poverty Research Group and Wang Research Group within the AIBN

~ Student whose research does not relate to Dow Centre projects

Student Name / Program	Advisor/s	Project Title
# Kushagra Bimalbhai Bosamia (Ugrad Thesis)	A/Prof Simon Smart Dr Rijia Lin	CO _x free Hydrogen Production using Membrane Reactors and Methane Pyrolysis
# Zachary Brown (Ugrad Thesis)	Dr Simon Smart Mojgan Tabatabaei	Techno-Economic Analysis of Electrolytic Magnesium Production via Process Coupling
# Clement Chan, PhD	A/Prof Bronwyn Laycock A/Prof Steven Pratt Dr Luigi Vandi Prof Peter Halley	Development of bio-derived and biodegradable polyhydroxyalkanoate (PHA)-based wood plastic composites
# Aidan Chin, PhD	Prof Susanne Schmidt Prof Gerhard Schenk Dr Richard Brackin A/Prof Bronwyn Laycock	Modernising organic wastes: optimising nutrient release for the future
# Benoit Clement, PhD	Prof Lianzhou Wang Prof Chris Greig	Development of future generation rechargeable flexible energy storage
# Mark Hodgson, PhD	A/Prof Simon Smart Prof Victor Rudolph	A global transition to low carbon economy - limits of possibility?
# Yuxiang Hu, PhD	Prof Lianzhou Wang Prof Kazuhiro Nogita Dr Delai Ye	Development of novel electrode materials for next generation rechargeable batteries
# Xia Huang, PhD	Prof Lianzhou Wang Dr Bin Luo Dr Ruth Knibbe Prof Eric McFarland	Design of new two-dimensional hybrid materials for lithium sulfure batteries
# Edward Jiang, PhD	Prof Darren Martin Dr Pratheep Annamalai Dr Bronwyn Laycock	Water-based processing of spinifex nanocellulose fibrils into continuous textile fibers
# Ian Levett, PhD	A/Prof Bronwyn Laycock A/Prof Steven Pratt Dr Christopher Pratt Dr Matthew Redding	Development of novel controlled release fertilisers for improved nutrient delivery efficiency
# Romy Listo, PhD	Dr Jennifer Munro Dr Peter Ralph Westoby Prof Chris Greig	Power to empower? Exploring the role of energy in women's organising and empowerment in rural India
# Yuwan Malakar, PhD	A/Prof Elske van de Fliert Prof Chris Greig	Social constructs of energy poverty and the resulting capability deprivations in rural India
# Sajna Manoj, PhD	A/Prof Bronwyn Laycock A/Prof Steven Pratt	Drivers and barriers for commercial applications of waste derived diesel
# Gabriel Rioseco, PhD	Prof Stephen Wilson Dr Joe Lane Dr Brian Fisher Prof Chris Greig	Electricity Modelling in Computational General Equilibrium Models under high Variable Renewable Energy Scenarios
# Songcan Wang, PhD	Prof Lianzhou Wang Dr Jung Ho Yun	Facet and defect engineering of metal oxide photoanodes for efficient photoelectrochemical water splitting
# Sara Zeinal Zadeh, PhD	A/Prof Simon Smart Prof Peta Ashworth Prof Chris Greig	Rapid Switch to de-carbonization of electricity generation sector: understanding the supply constraints and determining the maximum deployment rate of solar power
* Heidi Cooper, PhD	Prof Nicole Gillespie Prof Chris Greig Prof Karen Hussey	The rise of the disempowered citizen and its impact on the development of effective responses to the Climate-Energy nexus

Student Name / Program	Advisor/s	Project Title
* Heidy Cruz, PhD	Dr Ilje Pikaar A/Prof Bronwyn Laycock Prof Paul Lant	The fabrication and use of hydrogels as an innovative and cost-effective approach for targeted recovery of reactive nitrogen
* Franziska Curran, PhD	Prof Paul Lant Prof Chris Greig A/Prof Simon Smart Dr Justine Frances Lacey	Informing energy projects in developing countries by leveraging lessons learnt from the water sector
* Leela Dilkes-Hoffman, PhD	A/Prof Bronwyn Laycock A/Prof Steven Pratt Prof Paul Lant	The development and sustainability analysis of high-performance, multi-layered, biodegradable food packaging
* Russell Gordon, PhD	A/Prof Mary Fletcher A/Prof Bronwyn Laycock Dr Natasha Hungerford	Mitigating the effects of the plant toxin Simplexin on Australian livestock
* Johannes Grove, PhD	Prof Paul Lant Dr Simon Smart Prof Chris Greig	Energy transitions in developing countries and the role of alternative liquid fuels in reducing energy poverty
* Matthew Herington, PhD	Prof Paul Lant A/Prof Elske van de Fliert Dr Simon Smart Prof Chris Greig	Positive Deviance: understanding the generative mechanisms for social change and the alleviation of energy poverty
* Anthony Heynen, (PhD)	Prof Paul Lant Dr Simon Smart Prof Chris Greig A/Prof Srinivas Sridharan	Private sector electrification in base of the pyramid marketplaces in India: opportunities for energy and business to create shared value
* Amy Hodson, PhD	Prof Peta Ashworth Prof Chris Greig	Understanding societal attitudes to low carbon technologies
* Craig Jacobson, PhD	A/Prof Simon Smart Dr Ananthanarayanan Veeraragavan Dr Vigya Sharma	Applying systems modelling to tackle energy poverty challenge
* Mai Jingjing, PhD	A/Prof Bronwyn Laycock A/Prof Steven Pratt	Characterization and degradation of novel synthetic PHA Materials
* Tong'en Lin, PhD	Prof Lianzhou Wang Dr Bin Luo	Nano-materials for electrochemical energy storage
* Gabriel Lopes Fraga	A/Prof Steven Pratt A/Prof Bronwyn Laycock	Environmental footprint of catalytic depolymerisation
* Pawarisa Luangthongkam, PhD	Dr Steven Pratt Dr Bronwyn Laycock Prof Paul Lant	Biosynthesis of Polyhydroxyalkanoates (PHAs) in Methane-utilizing Mixed Cultures
* Amir Nemat Hayati, PhD	Prof Darren Martin Dr Pratheep Annamalai Dr Bronwyn Laycock Prof David Evans	Renewable textiles and foams reinforced with nanocellulose
* Thanh Tung Nguyen, PhD	Dr Michael Heitzmann Dr Luigi Vandi	Development of sustainable engineered structural panels
* Syarifah Nuraqmar Syed Mahamud, PhD	Dr Bronwyn Laycock Dr Steven Pratt Prof Paul Lant	Polyhydroxyalkanoate (PHBV) copolymer production using Methanotrophic cultures
* Andrew Pascale, PhD	Prof Paul Lant Dr Simon Smart Prof Chris Greig	The links between energy and human welfare
* Chen Peng, PhD	Prof Lianzhou Wang Dr Jung Yun	Development of efficient and stable perovskite solar cells
* Lingbing Ran, PhD	Dr Ruth Knibbe Prof Lianzhou Wang	High Voltage Lithium-Ion Batteries
* Thomas Reddell, PhD	Dr Ananthanarayanan Veeraragavan A/Prof Simon Smart	Biomass fired supercritical carbon dioxide power cycles: microgrid applications and modelling

Student Name / Program	Advisor/s	Project Title
* Beatriz Reutter Susaeta, PhD	Prof Paul Andrew Lant Dr Joe Lane	The environmental opportunities and consequences of reducing food waste
* Jiayong Tang, PhD	Prof Lianzhou Wang Dr Bin Luo	Two-dimensional hybrid materials for capacitive energy storage devices
Michael Tarbath (PhD) * School of Land and Food, University of Tasmania, Australia	Dr Tina Acuna (University of Tasmania) Dr Shaun Lisson, (Consultant to CSIRO) Dr Elizabeth Pinkard (CSIRO) Dr Bronwyn Laycock	Impact of clear polymer film on the growth and physiology of maize
* Yue Yuan, PhD	A/Prof Bronwyn Laycock A/Prof Mary Fletcher	Modelling the controlled release of toxins from a rumen environment
* Tianlong Zhang, PhD	A/Prof Bronwyn Laycock A/Prof Steven Pratt	Understanding catalyst performance in CPD diesel production from waste
- Pradeep Basnayake, PhD	Dr Michael Heitzmann Dr Luigi Vandi Dr Juan Torres Dr Juan Medina	Advancing the properties of bio-composites: A study of fire-retarding natural fibre reinforced plastics, and the development of a biodegradable bio-based composite
- Munkhjargal Bat-Erdene, PhD	Prof Lianzhou Wang Prof Alan Rowan	Two-dimensional nanostructured materials: synthesis and application
- Abdulaziz Bati, PhD	Prof Joseph Shapter Prof Lianzhou Wang	Investigation of carbon-based hybrid nanomaterials for perovskite solar cells (PSCs)
- Gloria Bravo, PhD	Prof Suresh Bhatia A/Prof Simon Smart	Engineering models of permeation in mixed-matrix membranes
- Liam Brownlie, PhD	Prof Joseph Shapter Prof Lianzhou Wang	N-Type doping of single-walled carbon nanotubes for Si-CNT Hybrid Photovoltaics
- Lee Burns, PhD	Dr Paul Luckman Dr Brenton Fletcher Prof Peter Halley	Modification and processing of starches for increased productivity in mineral flotation
- Alexander Corletto, PhD	Prof Joseph Shapter Prof Lianzhou Wang	Writing CNT Lines
- Mehri Ghasemi, PhD	Prof Lianzhou Wang Dr Jung Yun	Basics of charge generation in disordered optoelectronic materials
Maria Gokhale-Stec, PhD Fraunhofer-Institut für Betriebsfestigkeit und Systemzuverlässigkeit LBF	Prof Rudolf Pfaendner Prof Peter Halley (co- advisor, informal) A/Prof Bronwyn Laycock (co-advisor, informal)	Phase morphology development in post-extrusion drawn PLA/PE blends
- Emilie Gauthier, PhD	Dr Bronwyn Laycock A/Prof Rowan Truss Prof Peter Halley	Understanding and predicting environmental effects on degradation of oxo-degradable polyethylene blown films
- Nur Hamid, PhD	Dr Liu Ye, A/Prof Simon Smart Dr David Wang	Forward Osmosis (FO) Membrane-based technology in urbane wastewater treatment
- Mengmeng Hao, PhD	Prof Lianzhou Wang Dr Jung Yun	Development of novel quantum dots sensitized solar cells
- Jarrad Humphry, PhD	Dr Michael Heitzmann Dr Luigi Vandi A/Prof Rowan Truss Prof Darren Martin	Reactive processing as a novel processing route for high performance compositive manufacture

Student Name / Program	Advisor/s	Project Title
- Christian Kudisonga, PhD	Dr Luigi Vandi Dr Michael Heitzmann	Novel reactive transfer moulding of thermoplastic composite materials
- Charmaine Lamiel, PhD	Prof Joao da Costa A/Prof Simon Smart Dr Julius Motuzas Prof Xiu Zhao	2D-3D Carbon Mixed Matrix Membranes
- Christopher McMahon, PhD	A/Prof Simon Smart Prof Ian Cameron	Trace element modelling and optimisation in an integrated steel works
- Sabiha Monny, PhD	Prof Lianzhou Wang Dr Zhiliang Wang	Semiconductor nanostructure engineering for photoelectrochemical energy conversion
- Abdul Quader, PhD	Dr Thomas Rufford A/Prof Simon Smart	Evaluation of pressure swing adsorption systems for CO ₂ removal and liquefied natural gas production
- Gregory Siemon, PhD	A/Prof Simon Smart Prof Ian Cameron	Enterprise-wide optimisation in steelmaking
- Samira Siyamak, PhD	A/Prof Bronwyn Laycock Dr Paul Luckman	Tailored starch based hydrogels: Renewable material solutions for wastewater and agriculture industries
- Kelly Smith, PhD	Dr Maureen Hassall Prof Stephen Wilson	Using human factors approaches to improve energy management
- Armin Solemanifar, PhD	A/Prof Bronwyn Laycock Dr Albertus Mostert Dr Tuan Nguyen Ms Rhiannon Creasey	Bio-inspired conducting peptide nanowires
- Manh Tuan Vu, PhD	A/Prof Simon Smart Dr Rijia Lin Prof Suresh Bhatia	Mixed matrix membranes for H ₂ /CO ₂ separation
- Mu Xiao, PhD	Prof Lianzhou Wang Dr Bin Luo	New types of photocatalysts
- Yue Yuan, PhD	A/Prof Greg Birkett Dr Julius Motuzas A/Prof Simon Smart Prof Joao da Costa	Inorganic mixed matrix for liquid processing

2018 HDR conferrals

Student Name / Program	Advisor/s	Project Title
#Songcan Wang, PhD	Prof Lianzhou Wang Dr Jung Ho Yun	Facet and defect engineering of metal oxide photoanodes for efficient photoelectrochemical water splitting
*Johannes Grove, PhD	Prof Paul Lant Dr Simon Smart Prof Chris Greig	Energy transitions in developing countries and the role of alternative liquid fuels in reducing energy poverty
*Matthew Herington, PhD	Prof Paul Lant A/Prof Elske van de Fliert Dr Simon Smart Prof Chris Greig	Positive Deviance: understanding the generative mechanisms for social change and the alleviation of energy poverty
*Anthony Heynen, (PhD)	Prof Paul Lant Dr Simon Smart Prof Chris Greig A/Prof Srinivas Sridharan	Private sector electrification in base of the pyramid marketplaces in India: opportunities for energy and business to create shared value
*Andrew Pascale, PhD	Prof Paul Lant Dr Simon Smart Prof Chris Greig	The links between energy and human welfare
*Beatriz Reutter Susaeta, PhD	Prof Paul Andrew Lant Dr Joe Lane	The environmental opportunities and consequences of reducing food waste
-Emilie Gauthier, PhD	Dr Bronwyn Laycock A/Prof Rowan Truss Prof Peter Halley	Understanding and predicting environmental effects on degradation of oxo-degradable polyethylene blown films

STUDENT EXPERIENCE

EAIT Postgraduate Conference

The Dow Centre was proud to again sponsor the annual Faculty of Engineering, Architecture and Information Technology (EAIT) Postgraduate Conference in 2018.

This annual conference provides an opportunity for EAIT's postgraduate students to showcase their research to peers and mentors, and gives students an insight in to possible career options following graduation.

The conference, held in June 2018, brought together students, academic staff, and industry professionals to highlight the critical role of collaboration in research to achieve and maximise innovation.

Conference chair and PhD student Partha Narayan Mishra said solutions to most complex engineering problems demand

a synergistic approach across several specialisations, highlighting that innovation is fostered in environments that inculcate collaborative research.

Dow Centre Director Chris Greig attended the conference to present PhD candidate Leela Dilkes-Hoffman with the award for Best Oral Presentation in Session 1 of the conference.



STUDENT EXPERIENCE

SEnergy Event

In 2018 the Dow Centre supported the Student Energy Network's 2018 SEnergy Event, an event designed to encourage interest in sustainable energy research. SEnergy aims to improve students' creativity, promote innovative and novel thinking, and increase communication skills and employability.

SEnergy is an inter-disciplinary, inter-faculty, student-led discussion featuring a panel of eight student leaders addressing the trade-offs between raising the average Human Development Index and reducing carbon emissions.

Throughout the event, a number of questions were presented to a panel consisting of representatives from diverse backgrounds, political views and disciplines.

The 2018 event had approximately 150 attendees from a number of UQ student societies, including:

- » Engineers Without Borders UQ Chapter
- » UQ Chapter of the Society of Petroleum Engineers
- » Fossil-Free UQ
- » QUT Energy, Renewables, Environment and Sustainability
- » UQ Politics, Philosophy and Economics
- » UQ Effective Altruism
- » Doctors for the Environment Australia Students
- » UQ South Pacific Islander Association

This event provided an opportunity for students across faculties to create discussion around energy and sustainability issues, gain an understanding of the trade-offs between raising the average Human Development Index and reducing carbon emissions, and develop cohesive ideas and solutions.



STUDENT EXPERIENCE

Sustainability Innovation Student Challenge Award (SISCA)

Each year, the Dow Centre's Sustainability Innovation Student Challenge Award (SISCA) competition invites students to submit innovative ideas with a tangible engineering focus. The ideas need to address global sustainability issues through the production and use of energy and materials. Specifically, the SISCA competition requires students to prepare a comprehensive proposal for either an early-stage or a startup-ready idea.

Early-stage idea proposals required students to define a current problem in sustainability (including an analysis of the relevant economic, social and environmental impacts), provide a proof-of-concept to explain how their idea will help solve this problem, and outline how they will use the prize-money to further develop their idea. In addition to this, startup-ready business proposals required students to demonstrate the economic, social, and environmental impacts of their proposed solution, demonstrate scalability of their idea, and prepare a business plan outlining the economic opportunity and proposed use of prize-money.

Shortlisted entrants were invited to pitch their ideas at the SISCA finals and awards night in October 2018. Ideas were judged by a panel of expert UQ and industry professionals, including UQ's Professor Mohan Krishnamoorthy (Pro-Vice-Chancellor, Research Partnerships), Dr James Wiltshire (R&D

Technology Leader A&NZ, Dow Chemical Company), Mr Bernie Woodcroft (Director, ilab, UQ) and Mr Cameron Turner (BEL Faculty Entrepreneur in Residence, Startup Academy, UQ).

The Dow Centre congratulates all prize winners, who received cash-prizes to turn big ideas into an economically-sustainable business, and in turn make their positive impact on sustainability.

In late 2018, three SISCA competition winners were accepted into the 2019 UQ ilab Germinate Plus accelerator program. Alongside IdeaHub and the UQ Startup Academy, SISCA is one of many extra-curricular programs which supports UQ's growing community of entrepreneurs and change-makers.



2018 SISCA winners

STARTUP-READY IDEA PROPOSALS

First-place and \$25,000 prize: NPK (now Sustaen) - Ashley Baxter and Ashley Chiam

A medium-scale composting system that is low-cost, low-energy yet capable of producing commercial-grade organic fertiliser.

Runner-up and \$10,000 prize: H2Ope Greywater Filtration Systems - Tony Jojo, Mahealani Delaney, Ruhma Shahzad, Alexander Moore, Vanessa Poh, Emma Dahan and Edward Southall

A modular greywater treatment system which allows households to effectively utilise their water consumption, increase their sustainability around the house and also make an economic savings.

Second runner-up and \$2,500 prize: Affordable Biogas Plant System - Quan Shi

A new generation of biogas plant system which utilises a folding fabrication method and aims to help local families solve their renewable energy supply challenges.

EARLY-STAGE IDEA PROPOSALS

The Powersphere, \$5,000 prize - Hayden Baks, Qiushi Huang, and Alex Riley

An omnidirectional wind turbine capable of capturing wind from all directions, which can convert kinetic energy from wind to electrical energy.

Phytoplankton Carbon Sink, \$5,000 prize - Riannah Burns and Benjamin Coughlin

A method to replicate the biological pump outside of the ocean (in tanks) in a more efficient and controlled environment, in which 100% of the CO₂ is sequestered.

Sustainable Sand Alternative for Concrete, \$2,500 prize - Giulio Deane-Caleffi

A new approach to the use of Iron Ore Tailings, whereby waste is used as a sustainable alternative for sand as a fine aggregate in concrete.

Ref-tech Self-Powered Fire Detectors, \$2,500 prize - Anders Horgen Aaseboe, Raia Alballa, Peiquan Li, Xia Shi, Xueyan Chen, and Yiqun Xu

A self-powered fire detection unit that can communicate wirelessly with other units as part of a local area network.

Bon Courage, \$2,500 prize - Javier Rangel, Rosario Perez, Camilo Montoya, Nicholas Kang, Yepeng Ding, and Ju Yao

A rainwater collection and treatment system which aims to satisfy the water demands of the inhabitants of refugee camps by treating rainwater to a standard acceptable for use as potable water.

'Rapid' solution for insect free living, \$2,500 prize - Octovian Cletus Lawrence Vijayakumar, Yiquan Deng, Jagrat Shah, Abishek Waghmare, and Yilun Weng

A solar-powered insect control system which aims to mitigate insect-borne diseases, and utilise waste as feed for livestock or fertilisers.





2018's SISCAs Success

Final-year IT/Business Management student Ashley Baxter and Chemical Engineering student Ashley Chiam successfully pitched their bright idea for the management of organic waste at the 2018 SISCA finals, winning the \$25,000 first prize.

Ashley Baxter shared her experience on winning the competition, and her advice for other aspiring entrepreneurs.

What was your SISCA-winning idea 'NPK' about?

Our application for the SISCA competition was for an organic waste management business that utilised composting the waste into commercial fertiliser, targeting developing countries. The technology we are developing could completely decompose organic waste in only two weeks, using a wireless sensor array and analysis system.

How has your idea evolved since winning the competition?

After winning the 2018 SISCA competition, I took the idea to UQ's ilab, which I was accepted into, receiving an additional \$20,000 and 6 months' worth of residency and mentorship. Working on the idea full-time and with ilab's valuable mentors allowed me to refine it to the most valuable element, which was the technology that increased the decomposition of organic waste.

How do your ideas benefit communities, industry and/or the global community?

Organic waste causes significant environmental and social problems, producing up to 2% of total global emissions. Composted fertiliser is also exceptionally valuable, due to the intensive industrial processes required to manufacture artificial fertilisers, the reserves of which are also non-renewable. By simplifying and accelerating the decomposition of organic waste, the practice of composting will be far more accessible to people, households and communities, solving both of those sustainability problems.

What inspired you to look at this particular problem, and pursue your solution?

I have always been exceptionally concerned and passionate about sustainability. Throughout my work experience and education, I became more and more certain that it would be a massive part of my life. Of the countless sustainability issues in the world, I chose to focus on organic waste and fertiliser due to the lack of attention and action that it receives, despite being such a significant problem.

What is the unique selling point of your idea?

Compost monitoring systems of course already exist and have for decades, however these are simple and only collect data, relying on the user to interpret the results. Not only does our monitoring system collect relevant composting data but it translates the data into rich, meaningful, understandable information.

What skills or interests do you possess that will help bring this idea into reality?

In developing the original proposal, I worked with a Chemical Engineering student to validate the basic technology. I have since recently graduated from Information Technology and Business Management. These technical skills will help bring the technology to market.

In 2018, how did you use your prize money to progress your idea?

I haven't spent a significant amount of the \$25,000 to date, except for prototyping and early stage business set-up. Moving forward, most of the funding will be used in the coming four months for product development.

What would you say to other UQ students interested in sustainability?

Becoming a sustainable species is one of humanity's biggest challenges. Creating innovative solutions to these problems is an exceptionally meaningful, motivating and rewarding thing that absolutely anyone can do.

What would you say to other UQ students interested in entrepreneurship?

I would say "what are you waiting for then?!" If you're seriously thinking about entrepreneurship, you clearly have that little spark inside you so go and check out all the available programs at UQ, like SISCA and the IdeaHub, and see how you go!

What does 2019 have in store for you?

I'm currently looking to build up my team. While I have sufficient skills in myself and funding for any third-party work, I would definitely love for more people to come on-board for the exciting journey.

In 2019 I will continue to develop my start-up 'Sustaen' into a successful, sustainable company. The monitoring system will be available for commercial purchase by the end of the year, at which point the team will be built up to several sustainably-driven people, ready to take on even more sustainability problems!



H2Ope won \$10,000 as the runners-up of the startup-ready category in the 2018 SISCA competition.

Tony Jojo (Bachelor of Electrical Engineering (Hons) and Business Management) and the H2Ope team say the idea behind H2Ope was to produce a household modular greywater treatment system that will allow users to recycle the water they use, saving water, money, and creating a positive impact on sustainability.

“Our team members have seen how lack of access to fresh water has adversely affected communities around the world, especially given the prolonged drought conditions in Australia, so we wanted to try and make an impact on this sector. Our system (H2Ope) allows users to reduce their water usage by almost 25% and thereby make a big impact on preserving our freshwater resources” said Tony.

The H2Ope system is the only treatment system which is modular and accessible, meaning that homeowners or tenants can make use of this system regardless of the size/shape and space restrictions, making it more accessible and allowing users to have a direct impact on sustainability.

The H2Ope team is comprised of individuals from diverse educational, cultural and social backgrounds. Tony said that this diversity has provided a wider range of perspectives and helped them to create an innovative solution. In addition, half of the team had previous experience in working with startups, which brought valuable experience and industry connections to help them succeed.

H2Ope will use their prize money to design and prototype their product using 3D printing technology. Conscious of the challenge of water scarcity around the world, the H2Ope team are also working towards developing a model whereby a portion of their profits could be used to promote grassroots-

level water accessibility projects in developing nations. “We would love to get in contact with interested mentors and testing facilities as we strongly believe that experience and knowledge are great catalysts in producing exceptional businesses and products” added Tony.

“Our combined sustainable future is a key issue that needs to be addressed and a lot of the impactful decisions and solutions will probably come from this generation of students. The UQ Dow centre has been amazing in promoting sustainability and also provided a great platform to build on these solutions. The opportunities and support for entrepreneurship at UQ is phenomenal and I would recommend everyone gives it a red hot go before they graduate!”



The Powersphere

Hayden Baks (Bachelor of Engineering / Bachelor of Science) was part of the team who won the Early-stage idea category and \$5,000 in prize money for the design of the Powersphere – an omni-directional wind turbine capable of capturing wind from any direction.

“As a team we are passionate about renewable energy sources – in particular, overcoming and optimising limitations in prior technologies” said Hayden. While developing their winning proposal and pitch, the team found that there were currently no viable small-scale wind generators on the market which could be utilised in built-up urban areas, nor were there any marketed wind turbines capable of capturing wind from all directions simultaneously.

The Powersphere is a small-scale energy generation system that can be used to offset rising costs of living. The system has potential to provide a source of renewable and reliable energy to people living in regions of the world without reliable access to electricity. Hayden described the Powersphere as a sustainable carbon positive system which has the potential to reduce customer’s power bills and carbon footprint.

“We plan to use the SISCA prize money to patent our design and start manufacturing our final product with the intended materials so that we can undertake further testing.”

Since competing in the SISCA competition, the team have completed further system analysis and are now looking for mentors to help further refine their business strategy to bring the Powersphere to the market.

Hayden and his team believe that students should take advantage of the opportunities available to them to make a difference to sustainability.

“We think it is important to view common things in original ways. Looking at things you consume and use in your daily life and think, how could that be changed to adapt to a more circular economy. I would encourage those interested in sustainability or entrepreneurship to check out all the services and support available at UQ. From SISCA to Idea Hub and ilab,

there is a huge range of resources at a budding entrepreneurs’ fingertips. Whether you have a good idea or just want a place to start thinking check it out, who knows what could come of it!”

Update - SISCA winner 2017

Following his successful entry in the 2017 SISCA competition, Yousef Al-Qaryouti has applied his SISCA prize toward further developing his 'Deployable House', an innovative prefabricated house design, which provides an effective method for low-cost and rapid post-disaster reconstruction of safe accommodation.

In 2018, Yousef advanced his design by simplifying the construction methodology and reducing costs through the use of alternate materials.

To date, the first house has been experimentally tested to provide an insight into the structural resistance of the house to gravity and wind forces. These tests resulted in excellent structural performance, and provided data which has been used toward certifying the soundness of the design.

In 2019, Yousef will continue to refine his design and partner with industry representatives to grow his startup business, which is already receiving interest to develop a temporary and permanent housing solution incorporating solar panels and water supply for countries such as the Philippines, as well as Australia.

Thank you

The UQ Dow Centre warmly acknowledges and thanks each of our supporters for their stunning generosity throughout 2018, which enabled our researchers and students to pursue solutions to some of the world's most pressing environmental and social sustainability challenges.

Through the support of our valued donors and partners, the Dow Centre has furthered research into innovations in economically and environmentally sustainable processes associated with the production and use of energy and materials.

The Dow Chemical Company anchored the formation of the Dow Centre for Sustainable Engineering innovation in 2013 with an extraordinary gift and in 2018 reaffirmed their generous support.

In 2018, the generous support of the Trevor and Judith St Baker Family Foundation enabled the establishment of the Tritium Visiting Fellowship, a fellowship that advances research activities directed toward the performance, economics and uptake of e-Mobility globally. This research will inform public policy, investment decisions, technology innovation, public health studies and community behaviour to support the transition to sustainable, low-emission, electric-powered transportation.

The support of our donors has also provided scholarships for talented undergraduate and postgraduate students to undertake work-integrated learning, pursue a world-class education, and contribute new knowledge toward creating change that advances society.

Our sincere thanks to

The Dow Chemical Company

The Trevor and Judith St Baker Family Foundation

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Together, our greatest days lie ahead

Harnessing the passion and support of those who believe that engineering, innovation and sustainability plays a critical role in building a better world, will be vital to powering towards achieving our ambitions for a better world.

The Dow Centre supports UQ's *Not If, When* Campaign, which aims to galvanise the community and UQ alumni to help raise the funds required for three key priorities:

- » Empowering student success
- » Transforming teaching and learning
- » Driving Research and impact

UQ teaching and research outcomes continue to have a significant impact on people's lives, all over the world.

The Dow Centre Advisory Board Chair and Vice-Chancellor, Professor Peter Høj said "now, more than ever, our future will be shaped by donors and their vision for a better world."



Supporting change through the UQ Dow Centre

The support of our donors, partners, and the community advances the pathway toward a more sustainable, innovative and prosperous future for all.

Energy and Poverty Research Group: Alleviating energy poverty through achieving universal access to affordable, reliable and sustainable energy services.

Rapid Switch: Leading the global transition to a low carbon economy by understanding bottlenecks and constraints to decarbonisation.

Low CO₂ production of iron and steel: Forging a new process for the emissions intensive steel industry by reimagining how to make iron without CO₂.

Low-CO₂ hydrogen and fuels: A promising alternative pathway for the production of hydrogen and clean fuels without greenhouse gas emissions.

To read further about the work of the Dow Centre, please visit dowcsei.uq.edu.au, or contact us at dowcentre@uq.edu.au.

To learn more about driving discovery and impact through UQ's campaign to create change, please visit giving.uq.edu.au.

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