DOW CENTRE FOR
SUSTAINABLE ENGINEERING INNOVATION

ANNUAL REPORT 2016

The University Of Queensland
AUSTRALIA

Create change

Contents.

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Foreword
VICE-CHANCELLOR'S MESSAGE

As the Dow Centre for Sustainable Engineering Innovation enters its fourth year of operation and a new phase of research, innovation and talent development, I am pleased to introduce this annual report on behalf of the Dow Centre Advisory Board.

The Centre maintains the conviction that sustainable technological development must be environmentally and socially acceptable, economically viable and competitive.

Guided by this principle, the Centre has reached the final stages of many of its inaugural projects.

For example, the Centre's early core projects in carbon fibres, production of plastics using bromine chemistry, and low-cost ultra-safe nuclear energy have now been completed. Several publications relating to these projects have been published, submitted, or are in the final stages before submission.

I am pleased to report that three exciting new projects have emerged as flagship projects. The first stems from earlier methane conversion work and involves methane pyrolysis as a means to produce hydrogen and chemicals without CO_2 emissions. The second involves exciting advances on a new process to co-produce iron and petrochemicals without CO_2 emissions. And the third flagship project takes a unique look at the global decarbonisation challenge and at the constraints and bottlenecks likely to affect the delivery of new energy and industrial infrastructure – with some surprising outcomes.

In 2016, the Dow Centre helped the University to create change by inspiring the creativity and critical thinking necessary for developing economic and sustainable technology innovations. As illustrated in the feature on 'The next generation', the Centre has been particularly active in its teaching and learning and mentoring programs. Further, our new Dow Centre Sustainable Engineering Innovation Start-up (SEIS) program saw the award of $42,500 in prizes and/or grants to encourage and financially support entrepreneurial initiatives among engineering students.

On behalf of the Advisory Board, I congratulate Professor Chris Greig on guiding the Centre through a period of change in an increasingly uncertain global research environment. Under his leadership, and with contributions from a network of international collaborators, the Centre has secured exciting projects to pursue over the next few years. It is testament to the agility of the Centre that it continues to be relevant and a cornerstone of the University's commitment to create change on a global scale.

I also extend my thanks to the entire Dow Centre team, as well as their collaborators and partners across UQ and in industry and government, for their vital contributions in 2016.

Finally, I thank the Dow Chemical Company for its continued investment and support, which enabled the Centre to flourish in 2016.

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

01
INTRODUCTION

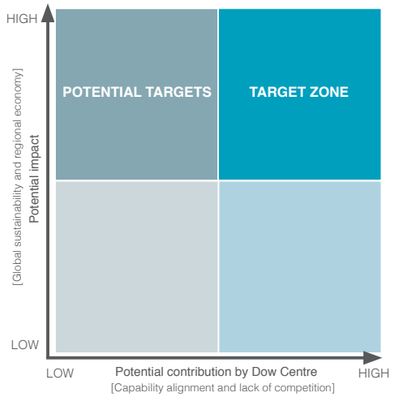
Director's REPORT

Sharpening the focus

2016 represented a transition year in which we sought to sharpen our focus toward a small number of flagship projects, through which the Dow Centre could make an original and significant contribution to areas that might move the needle on global sustainability. Naturally that left us with a vast array of opportunities and so, to align them with our major strengths and competencies, we narrowed our targets to the energy and materials space.

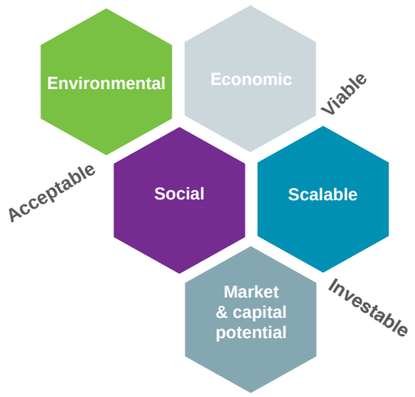
We also sought to position ourselves more prominently on the challenges of our region – those challenges which are of critical interest to Australian industry and its regional trading partners.

Even within this more focussed approach, there remained a plethora of high quality, relevant research opportunities for the Centre to consider. Screening those opportunities to maximise our potential for genuine impact became ever more critical with this deliberately more focussed investment strategy. All projects are therefore screened according to the following matrix:



In addition, we recognised that our potential for impact can come not only in the form of technological contributions but also through engagement to influence both public policy and community awareness.

Finally, as we investigated the opportunities that were presented to us from both within the Centre and from colleagues throughout the UQ academic community, we realised that we also needed to give more clarity to our meaning for the term sustainability. To this end we borrowed from the Five Capitals model and settled on the criteria, represented in the following infographic:



This approach saw three flagship projects flourish through 2016:

- Rapid Switch
- Low-CO_2 production of chemicals from methane
- Low-CO_2 production of iron

All three are presented in the Research section of this annual report.

The iron project has the potential for significant IP. We hope to file patents in 2017 after which we can seek third party investment in further research and development.

Rapid Switch has the potential to change the way the global policy community thinks about the challenge to decarbonise the economy and we hope to maximise the impact by leveraging this project into an international collaboration network.

In 2017, we hope to mature at least one more flagship project and a number of exploratory scoping studies are presently underway.

Aligning with UQ's Strategic Priorities

The Dow Centre maintained its connectedness with UQ's Strategic Plan under the three pillars of Discovery, Learning and Engagement.

Discovery

In addition to the three flagship research projects described above, the Dow Centre has been a major advocate and supporter of innovation among the UQ student cohort. Once again we hosted the Dow Sustainable Innovation Student Challenge Award (SISCA) attracting a record number of quality nominations. The finals were held on 24 October 2016 with HOME[3] taking out the major prize and Innovo and Movus the runners up.

In addition to the SISCA prize, in 2016 we launched the Dow Centre Sustainable Engineering Innovation Start-up (SEIS) Grants. The major start-up grant was also won by the HOME[3] team with seven small seed grants, the Early Concept Grants, awarded to other teams of young entrepreneurs. Each of these grants must be invested in helping progress their sustainable engineering innovation towards proof-of-concept over the ensuing year with mentoring and advice from Dow Centre staff.

Teaching and Learning

In 2016, The Dow Centre stepped up its role in developing future leaders with a comprehensive commitment to teaching in the faculty of Engineering Architecture and IT. This commitment is illustrated through our leadership and delivery of:

- Professional Practice and Business education to undergraduate and Masters level students
- Core modules in Masters of Sustainable Energy
- Energy Systems undergraduate courses

Furthermore all Dow Centre Research Fellows and research students are encouraged to be actively involved in teaching and mentoring engineering undergraduates. This has resulted in a steady increase in tutoring and supervision duties.

The Centre also hosted three BE/ME students for six month industry/research placements and several undergraduates on eight week summer research placements. These placements offer students an immersion experience in which they focus on an industrially relevant research assignment under the mentorship of one or more Dow Centre Research Fellows.

Engagement

Throughout 2016, The Dow Centre, often in association with the UQ Energy Initiative, sought to position itself as a significant voice in advancing sound policy and community awareness in matters associated with energy, sustainability and the industrial economy.

These efforts are exemplified by the following:

- Three sold-out UQ Energy Exchange Series breakfast events with global leaders from IEA, IPCC and the Princeton Environment Institute
- Ten UQ Energy Express Public Seminars
- Two State Library Meet the Public events on energy policy
- The Director's participation as Director of the Energy Policy Institute of Australia at the forefront of national Energy Policy Engagement
- The Director's participation in the Energy Forum and Clunies Ross Innovation Awards for the Australian Academy of Technological Sciences and Engineering (ATSE)
- Participation by several Dow Centre staff in multiple conferences and engagement with leading universities in USA, UK, China, India, Indonesia, and Kuwait
- Techno-economic advisory services to companies looking at innovative sustainability projects

Looking Ahead

In 2017, The Dow Centre looks forward to capitalising on the investment in our strategy and increasing our measurable impact.

We will also pursue some new specific targets:

1. A substantial increase in third-party research funding and leverage
2. Funding commitments to support the Dow Chair in Sustainable Engineering Innovation in perpetuity
3. One new Flagship project in the area of sustainable production of materials and energy
4. Increasing our profile as an important advocate in advancing innovation and sound public policy in areas of sustainable industrial practice for the energy and materials sectors

Professor Chris Greig, Director, March 2017

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ADVISORY BOARD

The Dow Centre is a centre within the School of Chemical Engineering in close collaboration with the Australian Institute for Bioengineering and Nanotechnology (AIBN), the Global Change Institute (GCI), the UQ Energy Initiative (UQEI) and the Centre for Coal Seam Gas (CCSG). The Dow Centre Director reports to the Dow Centre Advisory Board and the Head of the School of Chemical Engineering. The Dow Centre Advisory Board consists of members with interest and expertise in sustainability representing UQ and the Dow Chemical Company (Dow). The Board meets approximately three times a year. In 2016, the Board met on three occasions: 11 February, 6 July (teleconference) and 24 October.

PROFESSOR PETER HØJ, 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 from 1 June, 2007. 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 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 Australian Academy of Technological Sciences and Engineering and a Foreign Member (Natural Sciences Class) of The Royal Danish Academy of Sciences and Letters.

PROFESSOR ANTON MIDDELBERG, Pro Vice-Chancellor (R&I)
The University of Queensland

Professor Anton Middelberg is the Pro Vice-Chancellor (Research and International) at The University of Queensland, where he leads key aspects of the university-wide research and internationalisation portfolio. He obtained his Bachelor (1989) and PhD (1993) degrees from the University of Adelaide and his Master of Arts from Cambridge (2001). After appointment as the youngest lecturer in engineering at the University of Adelaide and a Fulbright Fellowship at UC Berkeley, he accepted a position at Cambridge University. There he was rapidly tenured and promoted twice against quota to become the Reader in Biological Engineering. In this role he was also member of the Governing Body of Selwyn College and a Fellow of the Cambridge-MIT Institute.

MR TONY FRENCHAM, Regional President South East Asia, The Dow Chemical Company

Mr Tony Frencham is the geographic leader for Dow in South East Asia, and he also leads Business Development for Dow across Asia-Pacific. He is based in Singapore. Previously, in 2016 he was the Managing Director and Regional President, Australia and New Zealand. With a business career spanning over thirty years, and the past twenty eight years with Dow, Mr Frencham has served in a variety of business and executive roles in Asia, Europe, the United States, the Middle East, and Australia. Mr Frencham earned a Bachelor of Applied Science with Distinction (Chemistry) from LaTrobe University in 1982, a Graduate Diploma in Applied Polymer Science from Monash University in 1987, and a Post Graduate Diploma in Management from Deakin University in 1994.

DR WEIGUANG YAO, Global Director, Asia Pacific Chief Technology Officer
The Dow Chemical Company

Dr Yao Weiguang is the Chief Technology Officer for Asia Pacific R&D. He is responsible for Asia-Pacific 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 currently works in consultancy as a Specialist Manufacturing Advisor. 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 also a past President and Director of the Australian Plastics and Chemicals Industry Association. Mr Williams also serves as chairman on the UQ School of Chemical Engineering Advisory Board.

PROFESSOR ALAN ROWAN, AIBN Director and Group Leader,
The University of Queensland

Professor Alan Rowan has performed his research at the interface of chemistry and biology with seminal and pioneering work on processive catalysis and functional self-assembly. His latest scientific achievement has been the development of the first truly biomimetic hydrogel which mimics the mechanic and functional properties of the extracellular membrane. This recent discovery has further established Professor Rowan as a truly innovative scientist, working toward understanding at the molecular level the functional of hierarchical materials and catalysis. Professor Rowan has published nearly 300 hundred peer-reviewed articles and books which were cited 12,000 times. He has had the pleasure of supervising more than 45 PhD students who have received their doctoral degree.

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 Institute 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 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 focused 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 focused 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 CHRIS GREIG
DIRECTOR

Transitioning the global economy to a more sustainable future will require significant innovation. The need for new and improved technologies which are cost effective, supported by appropriate policy and human capability has never been greater or more urgent.

Professor Greig's research focuses on energy transitions, techno-economic analysis, energy for development, mega-project implementation and carbon capture and storage. He is deeply engaged with industry and collaborates extensively with partners internationally. On the policy front, Professor Greig is a regular lead contributor on energy-related government submissions on behalf of UQ, ATSE and the Energy Policy Institute of Australia. On the teaching front, he created and runs the final year engineering course - Professional Practice in the Business Environment, and is guiding new graduate programs built around four pillars – Global Change, Professional Practice, Leadership, and Innovation. These courses are designed to provide graduating students with the knowledge needed to effect change and implement solutions in the real world, with improved decision-making capacity and a deeper, more mature and pervasive treatment of ethics and sustainability.

Professor Greig leads both the Dow Centre for Sustainable Engineering Innovation and the UQ Energy Initiative. Professor Greig is a Chemical Engineer with a PhD from the University of Queensland and is a Fellow of the Australian Academy of Technological Sciences and Engineering (ATSE). After graduation Professor Greig founded a start-up company to commercialise innovative process technology which he successfully ran for 15 years prior to its sale. After that and prior to joining UQ, he held senior executive roles in the construction, resources and energy sectors for over 10 years. He is a Non-Executive Director of Seymour Whyte Limited and the Energy Policy Institute of Australia and has held various other corporate and Government board positions including as Deputy Chairman of Gladstone Ports Corporation.

2016 HIGHLIGHTS

- Keynote address: BP-Princeton Carbon Mitigation Initiative annual conference in London
- Keynote address: McDonnell Academy International Symposium on Global Challenges

Publications

- Herington, M., Van de Fliert, M., Smart, S., Greig, C. and Lant, P. (2016). Rural energy planning remains out-of-step with contemporary paradigms of energy access and development. Renewable and Sustainable Energy Reviews.
- Parkinson, B., Greig, C., McFarland, E. and Smart, S. (2016). Techno-Economic Analysis of a Process for CO_2-Free Coproduction of Iron and Hydrocarbon Chemical Products. Chemical Engineering Journal.

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SENIOR STAFF

PROFESSOR ERIC MCFARLAND
SENIOR CONSULTANT

McFarland's career in engineering is devoted to solving problems related to the production of low cost sustainable power to drive continued global economic prosperity. It is the most important technical challenge facing human civilization.

Professor McFarland's research activities are focused on coupling fundamental surface processes with novel material systems to enable economically and environmentally sustainable production of chemicals and power in real industrial processes. His group at USCB is working on the use of new catalysts and materials for decarbonizing fossil fuels and producing chemicals without carbon dioxide. His group also investigates novel nuclear reactor designs to reduce cost and increase safety and allow the opportunity for coupling chemical production with power production. Professor McFarland teams with colleagues using state-of-the-art theoretical methods to guide and interpret experimental work using advanced theory and to develop conceptual process models to evaluate the techno-economic potential of new processes making use of the chemistry.

Professor McFarland studied nuclear engineering at U.C. Berkeley and the Massachusetts Institute of Technology (MIT) and later joined the Nuclear Engineering Department faculty. He moved to the University of California, Santa Barbara (UCSB) where his research focus shifted to chemical reaction phenomena and catalysis. From January 2014 till December 2015 Professor McFarland was the inaugural Director of UQ's Dow Centre for Sustainable Engineering Innovation. He is now Professor at UCSB and a senior consultant to the Dow Centre.

Professor McFarland has worked extensively with industry and started and led several technology companies based on university research.

2016 HIGHLIGHTS

- Delivered MIT Energy Initiative IHS Lecture, Plan B: Fossil fuels without CO_2

Publications

- A comparative technoeconomic analysis of renewable hydrogen production using solar energy, Energy Environ. Sci., 2016, 9, 2354-2371
- Solid suspension flow batteries using earth abundant materials, ACS Appl. Mater. Interfaces, 2016, 8 (3), pp 1759–1765
- Halogen-Mediated Oxidative Dehydrogenation of Propane Using iodine or molten lithium iodide, Catal Lett (2016) 146:744–754

DR BRONWYN LAYCOCK
SENIOR RESEARCH FELLOW

We face many global challenges and our role as scientists and engineers is to identify opportunities where we have the potential to make a significant contribution to solving those challenges.

Dr Laycock is currently working across a range of projects with a focus on materials for circular economy applications. A key area is the production and processing of biodegradable, bioderived polymers, including their fundamental crystallisation kinetics, compositional distribution and morphologies, mechanical property manipulation, and production of blends and (nano)composites for desirable properties and novel applications. The application areas in her research program include biopolymers (particularly polyhydroxyalkanoates), biocomposites, controlled release matrixes for pesticide and fertiliser applications, polyurethane chemistry, polymer foams, biodegradable packaging, carbon nanofibre production and peptide based conducting nanowires.

Dr Laycock is a Senior Research Fellow in the Dow Centre and a Senior Lecturer in the School of Chemical Engineering at The University of Queensland. Prior to joining the Dow Centre, she was a project leader and Deputy Program Leader within the CRC for Polymers. In this role, she managed a project that delivered an oxodegradable thin film polyethylene that was commercially licensed by Integrated Packaging. This work earned the team a Joint Chairman's Award for research/commercialisation (CRC for Polymers) and an Excellence in Innovation Award (CRC Association). As a former Senior Research Scientist (CSIRO Division of Molecular Science), she was also awarded the Joint CSIRO Medal for Research Achievement 2009 for her work on the extended wear contact lens project (within the Vision CRC), which was successfully commercialised by Ciba Vision as the Focus Day/Night and the O2Optix lenses.

2016 HIGHLIGHTS

- One of the PhD students, upon graduating, found employment with the prestigious Swiss Federal Institute of Technology in Zurich
- Key publication on lifetime prediction of biopolymers was accepted into Progress in Polymer Science (5-year impact factor 33.92)
- Presented to multiple industry and research groups at the 5th Sustainable Phosphorus Conference in Kunming and undertook field trips in Guangzhou
- Presented at the NextGen fertilizer conference on Heron Island in December 2016, which brought together leaders in advanced fertilizer manufacture and design and key international researchers in this field

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SENIOR STAFF

DR SIMON SMART
SENIOR RESEARCH FELLOW

I'm passionate about research having impact and right now the low CO_2 iron project is very exciting. Imagine if we were able to show a CO_2 free way of co-producing iron and chemicals – that would be game changing!

The main objective of Dr Smart's work is to tackle one of the largest challenges facing the world today, climate change, by developing and applying innovative chemical engineering solutions to reduce carbon emissions. To this end his research program has two main themes the first of which forms the focus of his Dow Centre fellowship: (1) developing materials, processes and enabling technologies for sustainable energy, chemicals and water production and (2) the role of energy in society, particularly the links between energy access, affordability and poverty.

He currently leads two of the Dow Centre's flagship projects: Rapid Switch and Low CO_2 iron/petrochemicals. Rapid Switch seeks to answer the question, "How fast can we decarbonise the global economy?", and is unique in all the climate and energy literature for taking an engineering-based infrastructure delivery approach. The Low CO_2 iron project is a technology disruptor for the iron industry using halide salt chemistry to dehydrogenate methane and transform iron ore into a salt that is easily electrolysed at moderate temperatures (<500C).

Dr Smart is a Senior Research Fellow in the Dow Centre for Sustainable Engineering Innovation and a Senior Lecturer 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 continues as the Deputy-Director of its latest incarnation, 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.

2016 HIGHLIGHTS

- UQ Foundation Research Excellence Award "Production of CO_2-Free Iron and Petrochemicals"
- Representing UQ at the UQ/SUSTech Engineering workshop to Southern University of Science and Technology, Shenzhen China as part of larger a VC-led UQ delegation

Dr Howard Fong - Senior consultant

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.

Dr Phillip Grosso - Senior consultant

Phil contributes to the Dow Centre by providing analysis of the economic and technical feasibility of chemical and other processes and also in the development of new and novel processes. Phil has over 55 years of experience in chemicals, minerals and metals industries and has extensive experience in a wide range of inorganic and organic chemicals as well as aluminum, magnesium and titanium metals. He also served as Vice President and General Manager of the Crystal and Electronic Products Division of Kaiser (later Engelhard).

Dr Khuong Vuong - Research Fellow

Khuong obtained his BSc (Chemistry and Biochemistry) from the University of Sydney, Australia. His PhD and BSc (Honours) are from the University of New South Wales in organometallic chemistry and catalysis. He has co-authored more than 25 journal papers. Khuong is interested in developing environmentally and economically sustainable chemical processes.

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 nine different Australian research groups, developing innovative tools for coupled environmental-economic analysis. Joe also managed the Dow Centre interactions with the Brisbane Airport Corporation and has been reviewing opportunities for solutions to sustainability challenges associated with water and plant nutrients management.

Dr Yi Gu - Postdoc. Research Fellow

Yi received her Bachelor of Science in Chemistry and Master of Science in Physical Chemistry from Fudan University (China) in 2007 and 2010 respectively. In 2012, she received another Master of Science in Chemical Engineering from Tufts University (USA). She was awarded her PhD in Chemical Engineering at The University of Queensland in 2015 and until May 2016 worked as a postdoctoral research fellow at the Dow Centre. Her research interest exists in developing novel processes and materials for clean energy and environment.

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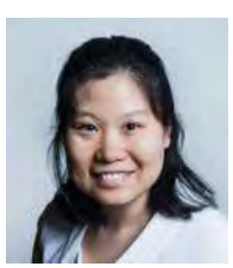
RESEARCH AND PROFESSIONAL STAFF

Dr Diego Schmeda Lopez - Postdoc. Research Fellow

Diego joined the Dow Centre in 2015, under the Rapid Switch Project. Previously, Diego worked as project and process engineer in the plastic and steel industries where he supervised the installation, commissioning and operation of production lines, participated in major refurbishments and supervised a team that analysed, identified and implemented efficiency opportunities. During his PhD, he researched the development of industry friendly metallic materials for membrane applications and developed stainless steel hollow fibres.



Dr Xiaoyu Wang - Postdoc. Research Fellow

Xiaoyu was awarded a Bachelor of Science in Materials Engineering from YanShan University, China in 2003 and a PhD in Chemical Engineering from The University of Queensland in 2014. She has a background in inorganic materials engineering and worked as a research chemist and laboratory manager in a chemistry laboratory centre in China for four years. She also worked on coal seam gas water treatment as her PhD topic. Xiaoyu joined the Dow Centre in 2014 after completion of her PhD. She is working in the areas of organic chemistry and sustainable energy technology.

Dr Benjamin Ballinger - Postdoc. Research Fellow

Ben's primary research focus is on the Rapid Switch project. His research interests centre around developing solutions to harmonise the economic, environmental and social trade-offs that exist within the water-energy nexus. Before joining the Dow Centre, Ben obtained his BEng (Chemical) in 2010 and PhD (Chemical Engineering) in 2015 from The University of Queensland. His research thesis focused on the membrane separation of CO_2 from pre-combustion processes. Ben has held professional research positions at both The University of Queensland and the CSIRO where his research focus has been on the separation of contaminants from both gaseous and liquid waste streams.

Mr Thomas McConnaughy - Analyst

During his time with the Dow Centre, Tom has worked on projects involving chemicals and energy. Tom was the project manager of the Dow Centre's program for improving sustainability of global methane utilisation, focusing on finding an economic opportunity for natural gas reserves. Tom was also engaged in TEA and process modelling of radiation chemistry involving photochemical process source economics. In July 2016 Tom left the Dow Centre to return to the United States where he currently works in a start-up company.

Ms Mojan Tabatabaei Zavareh - Analyst

Mojgan joined the Dow Centre to develop new process schemes by focusing on sustainability in energy and economics. She has a Master's Degree in Chemical Engineering from The University of Tehran and over 16 years of industrial engineering experience as a process designer, mostly in oil and gas processing. Mojgan is currently involved in a Dow Centre project on global methane utilisation and in halogenation based projects.

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RESEARCH AND PROFESSIONAL STAFF

Mr Brett Parkinson - Analyst

Brett graduated in 2014 from The University of Queensland with a Bachelors and Masters of Chemical and Materials Engineering (Hons). In 2015, following graduation, Brett worked temporarily as a consulting research officer for the Dow Centre, focusing primarily on process modelling of radiation chemistry, reactive distillation and halogen chemistry. Since his return to the Dow Centre in February 2016 Brett works mainly on the Low CO_2 production of Iron and Petrochemicals. Late 2016 he was awarded a Woodside John Monash Scholarship which will enable him to take up a PhD position at Oxford mid 2017.

Mr Callum Hickey - Analyst

Callum is a chemical engineer with a professional consulting background in environmental technologies, focusing primarily upon water treatment and also innovation.
He has a passion for technology, innovation and engineering, particularly where these topics overlap with a strong business focus. This passion led him to work at the Dow Centre, conceptualising and screening sustainable technology ideas through a techno-economic framework. In July 2016 Callum left the Dow Centre to take up a new position at QUTBluebox.

Mr Lucas Rush - Research Assistant

At the end of 2015, Lucas graduated with a dual Bachelor's degree in Chemical Engineering and Mathematics from The University of Queensland. During his undergraduate degree Lucas completed a research thesis on the applicability of using gamma rays as an initiation source for chemical production under the supervision of Professor Eric McFarland. This work led to a temporary position at the Dow Centre where he worked on the methane utilisation and nuclear energy projects. August 2016 he moved to the US to take up a PhD in Nuclear Engineering at MIT

Mr Ben Kefford - Research Assistant

Ben graduated from the University of Queensland in 2016 with a Bachelors and Masters in Engineering (Mechanical and Aerospace), where he was distinguished as a UQ Future Leader for his extensive work in research both domestically and internatonally. Following graduation, Ben joined the Dow Centre as a Research Assistant with the goal of advancing the methodologies used in the Rapid Switch project. His primary research interests lie in modelling the material and labour constraints surrounding the decarbonisation of the global energy sector, and how much of a role sociopolitical factors will play in the transition.

Ms Celestien Warnaar - Centre Manager

After moving to Australia and qualifying as a business administrator, Celestien took up a position at The University of Melbourne in 2004 and has since worked in several senior administrative roles. In 2009 she joined the ARC Centre of Excellence for Functional Nanomaterials at The University of Queensland, and worked as its Centre Manager, taking responsibility for the Centre's operational needs. In July 2013 she joined the Dow Centre where she assists the Director and manages all operational matters.

01
RESEARCH AND PROFESSIONAL STAFF

Our year in review

RESEARCH AND DISCOVERY - INNOVATION - ENGAGEMENT

The rapid switch project

A global transition to a low carbon economy: Limits of possibility

Anthropogenic induced climate change now has broad scientific and public consensus. While 2°C is widely seen as the upper limit in the trade-off between environmental risks and economic growth, current trends on carbon emissions are likely to result in an average temperature rise over 4.5°C by 2100. Even, post-COP21 in Paris, the collective (non-binding) commitments of nations are projected to result in an average temperature rise of about 2.5-3°C.

Studies on pathways to decarbonise the world's economy are now frequent, typically focusing on limiting cumulative CO_2 emissions by minimising total system cost assuming that low-carbon systems supply can always rise to meet demand. Very few consider constraints and vulnerabilities in the supply chains of the diverse low-carbon technologies and society's capacity to carry out the necessary additional infrastructure megaprojects concomitantly on a scale never before seen. In addition to these uncertainties, socio-political and economic factors have an important influence over infrastructure deployment and could further limit the capacity for industry to achieve the required rates of decarbonisation.

This research program aims to respond to these uncertainties, identifying and quantifying constraints and optimising supply chains across multiple sectors, thus providing an achievable maximum decarbonisation rate to 2050. The importance of this work lies in creating credible scenarios to inform political and corporate decision makers, helping direct efforts to address these constraints and maximise the efficacy of public and private policies to mitigate and adapt to climate change.

Key people

- Ben Ballinger
- Chris Greig
- Mark Hodgson
- Ben Kefford
- Diego Schmeda Lopez
- Mitchell Small (Carnegie Mellon University)
- Simon Smart
- Gabrielle Wong-Parodi (Carnegie Mellon University)

KEY OUTPUTS 2016

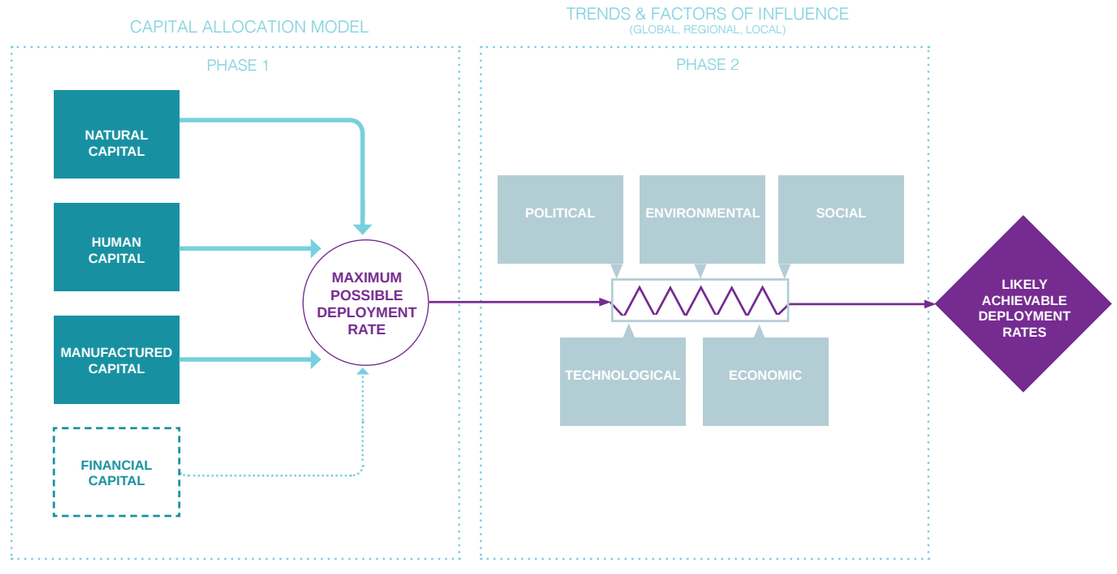
- PhD student (Sara Zeinal Zadeh) examining the solar power wedge
- PhD student (Mark Hodgson) recruited and due to start in Jan 2017
- Three papers in draft
  - *Can the world count on wind power in the fight against climate change?*
  - *Modelling the sociopolitical and economic constraints of a global energy sector decarbonisation*
  - *The vulnerability of rare earth supply to global decarbonisation*

Research report

The broad approach of Rapid Switch allows the identification of constraints and bottlenecks on both a global and regional scale, differentiating it from other work. This work approaches the calculation of deployment rates in three phases as shown in Figure 1. The first phase utilises a five-capitals framework to obtain the maximum rate of deployment achievable for low carbon technologies. This phase assumes an "all in" global approach to decarbonisation with deployment rates limited by capital stocks of resources, skills etc.; social/political/economic factors are assumed to be non-constraining in this phase. An optimisation model has been constructed to complete phase 1 and data collection is currently underway. Data on human, resource and manufactured capital is being sourced from academic literature, industry reports and expert elicitation.

The second phase of the Rapid Switch project aims to understand how socio-political and economic factors may result in the underutilisation of industrial capacity, thus limiting the real world deployment rates that may be achieved. A conditional probability network has been set up to complete phase 2 and data collection is currently underway. Data is being collected through surveys sent to a wide range of experts. Initial work is focussing on experts from carbon capture and storage, and once the methodology is confirmed, will be expanded to all current and future industrial scale technologies in the electricity generation sector. Finally, the third phase of the Rapid Switch Project is to combine both methods to obtain a rate factoring in both global capital stocks, economics and socio-political factors. This phase will take place after both phases 1 and 2 have been completed.

In parallel to this main rapid switch project, literature reviews are being conducted with the aim of building a body of literature surrounding technological constraints for global decarbonisation. The first review on wind turbines found that their deployment only faces a low probability of constraints in a scenario where a 2°C carbon budget is achieved. This is because the current deployment rates match those required to reach the 2°C target. The possibility of constraints arises from the lack of information surrounding the competition for resources from other low carbon technologies. This issue is scantly discussed in literature and supports the main motivation behind the Rapid Switch Project.



Capital allocation & optimisation model

*Schematic representation of the Rapid Switch method for deployment rate calculation. *Financial capital not included in initial calculations*

Increasing the sustainability of methane utilization

Creating novel processes using the chemical potential of methane without the production of carbon dioxide

The Dow Centre has interest in developing innovative process options for using natural gas for production of chemicals and power without carbon dioxide emissions. Early work examined how thermal and radiation chemistries might be integrated to a CO_2 free natural gas process by utilizing a halogen-based chemistry. The result of Techno-Economic Analysis (TEA) of a small-scale natural gas plant with applying the mentioned concepts shows no compelling economic advantage is achievable under optimistic assumptions.

The recent work has focussed on large-scale, CO_2 free, chemical production using a molten salt and halogen based chemical looping process. The Centre team, in collaboration with the University of California, Santa Barbara (UCSB), has been investigating and developing a new pathway using a new reactive separation concept that simplifies the process and reduces the capital cost.

The Dow Centre team has been an active collaborator with UCSB to show that molten metal salts and molten metals are effective media for pyrolysis of methane to produce hydrogen gas and solid carbon and have taken the lead on the process TEA making use of the experimental results from UCSB. Figure 1 shows a number of potential CO_2 free processes for methane utilization that are under investigation.

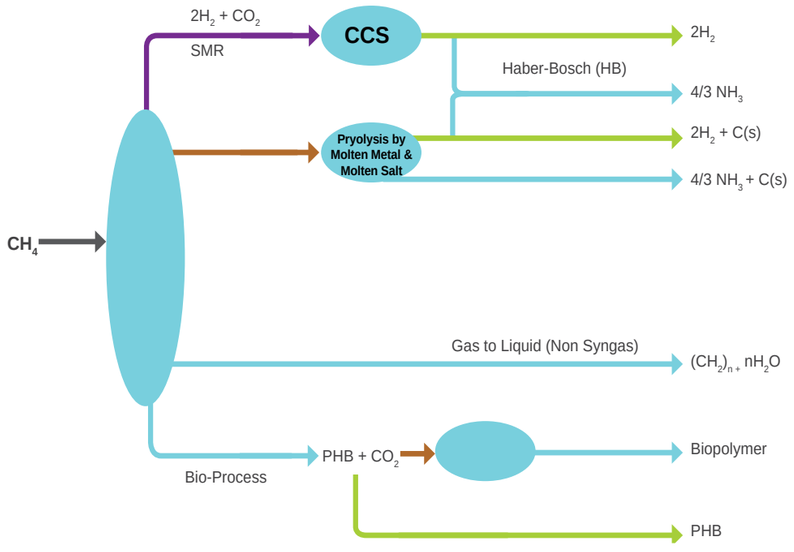


Figure 1: Methane utilization to power and chemicals without CO_2

Key people

- Howard Fong
- Eric McFarland
- Brett Parkinson
- Simon Smart
- Mojgan Tabatabaei
- Khuong Vuong

KEY OUTPUTS 2016

- Publication:
  Molten salt chemical looping for reactive separation of HBr in a halogen-based natural gas conversion process, Chemical Engineering Science,160 (2017) 245–253). Electronic copy published and available in 2016

Research report

Among the fossil resources, natural gas offers the greatest energy potential per unit CO_2 emission at a competitive cost. Although total carbon emissions associated with chemicals production are relatively low, the economic use of methane to produce a variety of chemicals through a cost effective process without carbon dioxide production would be of long-term scientific and economic interest. The Dow Centre has been investigating novel uses of natural gas:

1. Natural Gas to Chemicals without CO_2

This approach investigates an alternative pathway for methane partial oxidation using halogens as the oxidant rather than oxygen to make readily transformed and separated methyl halides as an intermediate. Methylhalides behave chemically the same as alcohols and over zeolite catalysts produced olefins, aromatics, and heavy hydrocarbons through oligomerization. Hydrogen halides can be separated and recovered through our new chemical looping process using a molten salt mixture with a metal oxide suspension. The experimental results of the oxygen reaction with the molten bromide salts show rapid and efficient production of molecular bromine and a suspension of the active solid metal oxide. The work to date has focussed on $NiBr_2$ / NiO in an unreactive KBr-LiBr eutectic melt. The process model of the chemical looping cycle indicates significant process simplification compared with conventional Gas-To-Liquids processes or processes using HBr catalytic oxidation. Additional investigations with chlorine based chemical looping chemistry, in presence of LaOCl as the active metal oxide and a mixture of LiCl/KCl for production of 500 kta of heavy hydrocarbon were also undertaken. The results show the potential for a CO_2 free process at comparable capital cost and a higher thermal efficiency than the conventional, CO_2 intensive, process.

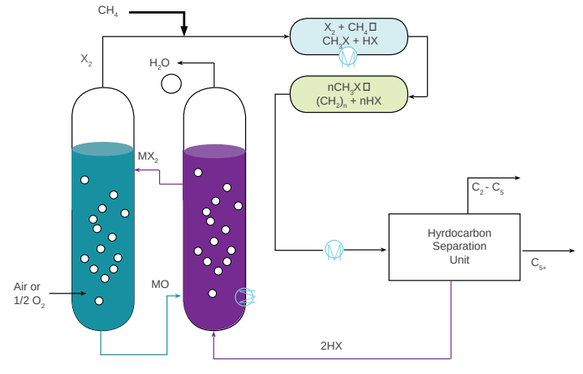


Figure 2: Methane to heavy hydrocarbon by chemical looping process

2. Methane to Hydrogen

Methane pyrolysis to produce molecular hydrogen and solid carbon is under investigation as the most direct and cost-effective means of producing hydrogen without carbon dioxide. Historically, the solid carbon produced proved costly to separate and remove. The major process challenges are the solid carbon separation and reactor design. We are investigating the use of molten metals and salts for methane pyrolysis whereby the separation of the carbon is a liquid-solid separation much like slag removal in blast furnaces. The Centre performed TEA for methane pyrolysis based on molten metals compared to steam methane reforming (SMR) for the industrial production of 200 kta of hydrogen. The results show that the hydrogen production cost is sensitive to the methane conversion, reactor temperature, and value obtained for the solid carbon by-product. The pyrolysis process is potentially competitive with SMR where metal can be catalytically active at a temperature of 1000°C or lower.

Extensive investigations are ongoing to provide the data needed for a quantitative TEA evaluation of the pyrolysis process as an alternative for the production of electricity (by combustion of the hydrogen) and chemicals such as ammonia.

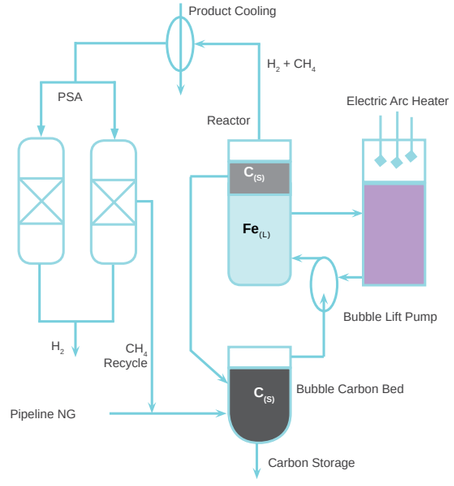


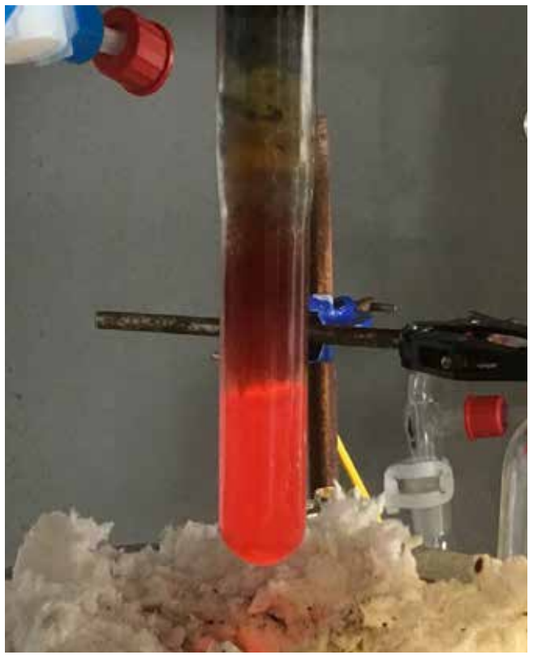
Figure 3: Methane pyrolysis in molten metals

Low CO_2 Iron Program

A technology disruptor for the iron industry

The agreements reached at the Paris COP21 conference in late 2015 committed to significantly reduce GHG emissions in order to keep global average temperatures well below 2°C. This is expected to require deep cuts in GHG emissions and ultimately net-zero emissions in the second half of the century. It is generally expected that a price will be placed on atmospheric carbon emissions during the coming decade creating the economic incentive to decarbonise. Manufacturing industries are responsible for approximately 30% of global CO_2 emissions and iron and steel production is the largest industrial source of direct CO_2 emissions estimated to be about 6-7% of the total global anthropogenic emission. The majority of these emissions come from the high temperature reduction of iron ore with coke in a blast furnace. It is a significant challenge for large producers of metals and chemicals to remain cost competitive whilst simultaneously lowering emissions and maintaining process energy and feedstock efficiency. Decarbonisation of the steel industry is mainly proposed through carbon capture and storage at a cost which has been estimated between $70 and $120 per tonne of CO_2.

This program is a technology disruptor for the iron industry that uses molten iron halide salt chemistry and electrolysis to co-produce iron and organic chemicals without making CO_2.



Molten $FeCl_2$ eutectic salt mixture

Key people

- Chris Greig
- Eric McFarland
- Brett Parkinson
- Simon Smart
- Mojgan Tabatabaei
- Khuong Vuong

KEY OUTPUTS 2016

- B. Parkinson, C. Greig, E. McFarland, S. Smart, T*echno-economic analysis of a process for CO_2-free coproduction of iron and hydrocarbon chemical products*, Chemical Engineering Journal, 313 (2017) 136-143
- UQ Foundation Research Excellence Award 2016 – $98.5k (Simon Smart)

Research report

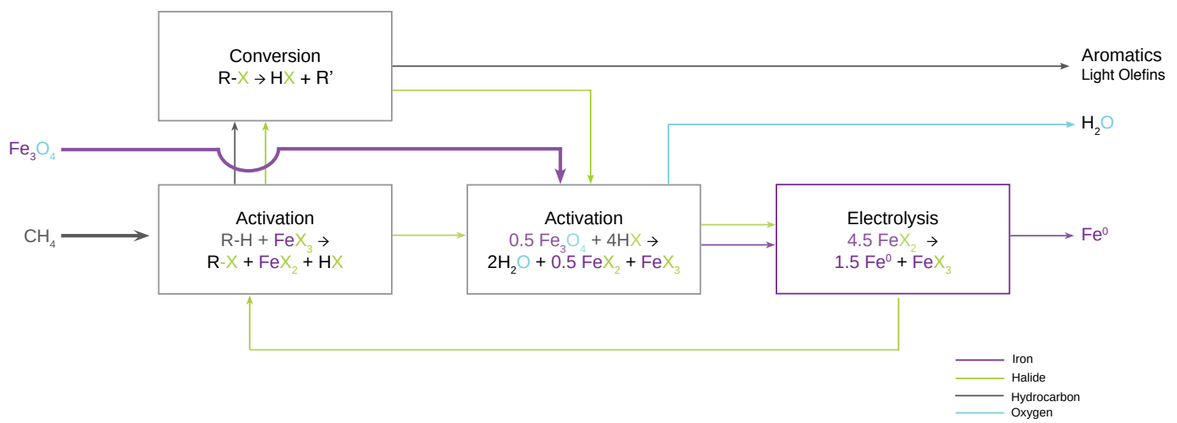
We propose a unique process that couples the reduction of iron ore with the partial oxidation of natural gas alkanes to co-produce iron and organic chemicals. Iron ore is upgraded by reaction with hydrogen chloride and the iron chlorides electro-reduced to the iron product. The oxidized iron chlorides are used for reaction with methane to produce the methyl-chloride intermediates. These are subsequently converted to hydrocarbon chemical products and the hydrogen chloride reused. No CO_2 is produced, except in the production of electricity for electrolysis. The integrated process overcomes the limitations of the conventional iron ore electrolysis and methane partial oxidation processes using halogens through:

- Substitution of the pure halogen for a liquid metal halide ($FeCl_3$) as the oxidising agent to advantageously manage the exothermic heat load
- Leaching iron ore with the inorganic acid (HCl) generated as a by-product to create a higher-value iron feedstock to an electrolyser (eliminating the major feedstock cost for leaching on the iron side)
- Regeneration of the iron chloride feedstock via the production of reduced iron from electrolysis (eliminating the major regeneration cost of the halogen)

To date we have completed process modelling and a first order techno-economic assessment of a production process that co-produces iron and hydrocarbon products and makes use of process integration and process intensification for overall efficiency and economic gains.

The first published paper [see under outputs] addressed the following:

- Estimated capital and operating costs of the integrated process
- Sensitivities of the costs to the major process uncertainties
- The price of CO_2 (~30 US$/t$CO_2$) that is needed for such a process to be economically competitive with present commercial processes (blast furnace iron making)



Simplified process block flow of the proposed process

Bromine Chemistry

In early 2015 an agreement with Israel Chemical Limited (ICL) was signed. It involved co-funding two researchers, ICL Fellows, to work on Bromine Chemistry. Two projects commenced and were reported on in the Dow Centre 2015 Annual Report. The work found that neither offered an economic value proposition. As a result it was decided on mutual agreement to terminate the agreement after the year 1 stage-gate. Further activity on the two projects was limited to the minimum work necessary to publish the results.

A third Dow Centre funded follow-up project was undertaken but also terminated in December 2016 due its lack of feasibility.

Bromine mediated photochemical dehydrogenation chemistries

The selective monobromination of hexane is demonstrated in a photochemically activated reactive distillation process. Bromine is contacted with hexane within a distillation column and activated by UV light. The radical mediated bromination proceeds within the column, the relatively high boiling monobromohexane is separated to the bottom and the low boiling hydrogen bromide removed at the top. Experimental results were supported by the process modelled in ASPEN and indicated that high selectivity for production of mono-substituted alkylbromides is possible with reactive distillation.

Since July 2016, only work which was considered necessary to complete a manuscript for publication from this project was carried out.

Collaborators

- UQ: Xiaoyu Wang, Yi Gu, Eric McFarland and Simon Smart (Dow Centre), Craig Williams (SCMB)
- ICL: Reinhard Effenberger, Joseph Zilberman

Key outcome

1. A novel reactive distillation column for the production of high selectivity monobromohexane and high conversion of bromine was designed.
2. Manuscript entitled: “Process Intensification by Photochemical Reactive Distillation” is 80% prepared for journal paper submission.

Isocyanates and diphenyl carbonate using bromine based chemistry

The synthesis of dialkyl carbonate (dimethyl carbonate and dibutyl carbonate) by a one-pot reaction using bromine, carbon monoxide and alcohol was demonstrated using a novel silica catalyst. The use of silica as a catalyst in this chemical process as well as in other carbon monoxide halogen processes offers significant potential. To the best of our knowledge, no previous studies have reported using silica as the catalysts for the production of these commodity chemicals. We developed a zero-order process model based on laboratory results. This suggested no clear cost advantage for this process compared to existing and planned commercial processes because alcohol is the required feedstock. Since July 2016, only work which was considered necessary to complete a manuscript for publication from this project was carried out. However, the Dow Centre funded further research into a follow-up project (Project 3 below).

Key partners

- UQ: Khuong Vuong, Eric McFarland and Simon Smart (Dow Centre), Craig Williams (SCMB)
- ICL: Reinhard Effenberger and Joseph Zilberman

Collaborators

1. A novel method for the synthesis of dimethyl carbonate from carbon monoxide, bromine using porous glass as the catalyst.
2. Manuscript entitled: “Dimethyl carbonate (DMC) synthesis via *in situ* generated carbonyl dibromide on porous glass” to be submitted to Chemical Communications in the first quarter of 2017.

The production of dimethyl carbonate from methane (self-funded by Dow Centre)

First order techno-economic analysis using the laboratory results from phase 1 of the collaboration with ICL found no compelling advantage for our method of producing dimethyl carbonate (from carbon monoxide, bromine and methanol) over current methods for the production of this chemical. As dimethyl carbonate is a widely used chemical with significant growth of more than 5% predicted, a low cost method for the production of this chemical would be highly beneficial.

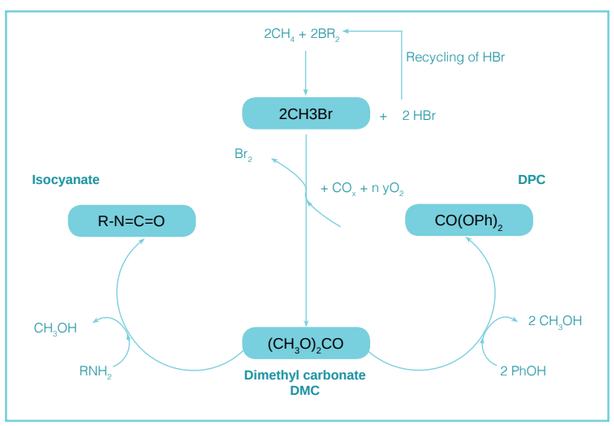
We therefore proposed a new method (see figure below) for the synthesis of dimethyl carbonate starting with methane as a feed-stock. A basic operating cost analysis of the processes indicated that the process could be competitive with current methods for the production of DMC.

Collaborators

- Khuong Vuong, Eric McFarland and Simon Smart (Dow Centre), Craig Williams (SCMB)

Key outcome

When screening the catalyst no formation of a desired dialkyl carbonate could be found.



Carbon Fibres

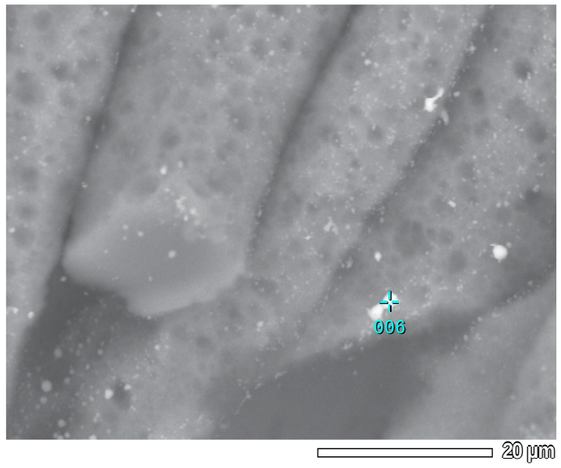
In 2014 the Dow Centre started research into the production of lightweight carbon fibres. This project was partly funded by Dow Chemical (Australia) through a grant that was independent of the Dow Centre funding. Funding for this project continued in 2015 and the Annual Reports of 2014 and 2015 both reported on progress in this project.

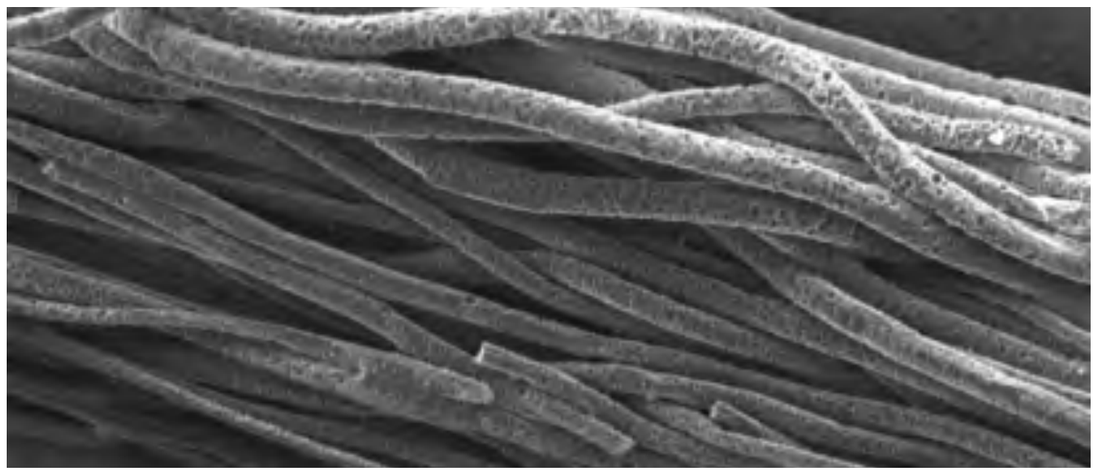
In July 2015 the Dow Centre and its partners, Deakin University and Dow Chemical (Australia) were awarded an ARC Linkage Project to continue the work on Carbon Fibre. Due to a change in strategy, Dow subsequently withdrew from the project. Although several other potential industry partners were approached, due to IP restrictions, no new partner could be secured and the grant had to be relinquished. During 2016 the Dow Centre worked on several publications related to the Carbon Fibre project which will be ready for publication in 2017.

A number of publications are in preparation. In addition, Bronwyn Laycock has presented at the Carbon Fibre Futures Conference 2017 in Geelong.

Collaborators

- UQ Dow Centre: Eric McFarland, Bronwyn Laycock, Xiaoyu Wang, Jorja Cork
- UQ AIBN: Darren Martin, Pratheep Annamalai
- Swinburne University: Bronwyn Fox (early 2016 she moved from Deakin University to Swinburne University)
- Dow Chemical (Midlands): Chris Derstine, Mike Mills





Next Generation Fertilizers

In 2014 a successful submission to secure financial support for a workshop was made under the Dow Centre's Pitch program. The objective of the workshop was to bring together several stakeholders to scope the potential and funding options for the development of the 'Next Generation Fertilizers' (see also 2014 Annual Report).

Some preliminary work is underway, funded by an RR&D4P grant led by the Department of Agriculture and Fisheries (DAF) and with funding from Sugar Research Australia and the Cotton RDC. A PhD student, Ian Levett, is developing detailed Matlab-based models of controlled release of active agents from a range of material types and morphologies. This baseline work will identify optimum processes and materials for matching product requirements (both encapsulation of soil active agents and controlled release of fertiliser). In parallel, he is also preparing materials for testing at DAF, where nitrogen transformations in both the presence and absence of crops can be analysed. Ian has just won two scholarships for this work, one the Warwick Olsen (UQ) and the other a Sugar Research Australia (SRA) Scholarship.

A second student, Rhys Pirie will work on the plant-fertiliser interactions. A BE/ME student, Phillip Raven, has just completed a semester on the topic of nutrient delivery from repurposed wastes, with samples being pelletised and used for cotton field trials. Results are pending. A postdoctoral research fellow will start work on novel formulations in July 2017.

Collaborators

- UQ: Bronwyn Laycock (Dow Centre), Susanne Schmidt (SAFS), Steven Pratt and Paul Luckman (Chem Eng), Damien Batstone (AWMC)
- Department of Agriculture and Fisheries: Matt Redding and Chris Pratt
- Industry partner: Manildra Starch

Key outcomes

Advance Queensland Innovation Partnership proposal submitted January 2017 – Partner Manildra Starch

02
RESEARCH - OTHER PROJECTS

Energy systems analysis to improve planning

Given the growing complexity of Australia's electricity networks, models that balance supply and demand across the power system are required for meaningful, quantitative analysis of planning scenarios.

Through collaboration with UQ's School of Information Technology and Electrical Engineering, the Dow Centre is working to improve the flexibility and rigour of power systems planning in Australia. A test-case for the Queensland network is being used to develop a modelling framework that can (a) identify the optimal electricity infrastructure mix given different levels of greenhouse gas mitigation, and different transition constraints; and (b) provide detailed assessment of real-world transmission constraints.

We also envisage a role for a simpler model that can provide rapid and robust screening analysis in response to changing policy debates. For this purpose, an existing model developed by the University of Sydney is under review, as its flexible architecture makes it suitable for configuring a broad range of scenario simulations. That particular model could also be modified for application in developing countries undergoing rapid electrification, such as in India, where improved power systems scenario analysis could help balance local economic development objectives with greenhouse gas mitigation concerns.

Collaborators

- UQ School of Information Technology & Electrical Engineering
- UQ Energy Initiative
- UQ Energy and Poverty Research Group

Energy Poverty in India

The Energy and Poverty Research Group (EPRG) formed in 2014 under the guidance of Prof Paul Lant, Prof Chris Greig and Dr Simon Smart.

The group now consists of more than five affiliated academics, two postdoctoral fellows and nine PhD students. In 2014 the group submitted a successful pitch to the Dow Centre and secured funding for two PhD Students focussed on social issues for the Energy Poverty challenge:

- Mr Yuwan Malakar passed his confirmation in July 2016 and is working on "The Social Constructs of Energy Poverty in India". As part of his work Yuwan published "Who is energy poor? Revisiting energy (in)security in the case of Nepal" in Energy Research and Social Science and presented a paper at The Royal Geographers Society annual conference in London in August 2016.
- Ms Romy Listo passed her confirmation in November 2016 and is working on 'Power to empower? Exploring the role of energy in women's organising and empowerment in rural India'.

Self Cleaning Membranes for tallow recovery from abattoir wastewater

Abattoirs utilise large quantities of water for the cleaning and sterilisation of meat processing equipment. The wastewater collected from these operations may be purified on site through primary and secondary treatment, with an optional tertiary treatment stage for water reuse. The Dow Centre ran a small proof of concept bench scale pilot trial, funded by the Australian Meat Processing Council, to investigate the full scale benefits of membranes which can be actively defouled using electrochemistry in the Red Meat industry for tallow recovery. Stainless steel membranes were used and potentials ranging from -3V to +2V applied either continuously to prevent fouling (called antifouling) or periodically to remove fouling build up (defouling). Both methods were effective at improving membrane performance but continuous antifouling at reductive potentials less negative than H_2 production gave the best performance. Unfortunately for this particular high fouling feed water the energy requirements were still too great to show commercial potential.

Collaborators

- Australian Meat Processing Council, Dow Centre, Functional Interfacial Membranes and Materials (FIM2Lab)

Key outcomes

- Two papers are currently being drafted on defouling and antifouling using applied potential on a stainless steel membrane, with an expected submission date of April 2017.
- Ms Julia Mueller, graduated from the project with her MPhil in December 2016.

Polyhydroxyalkanoate based wood plastic composites

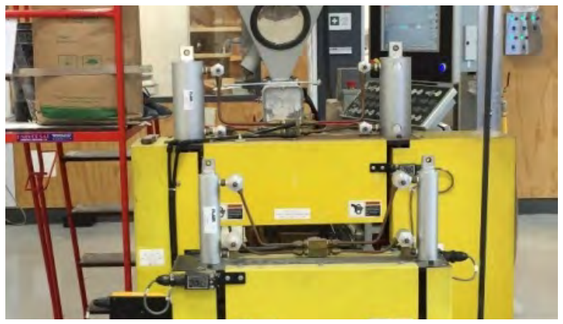
Commercially relevant composites have been made using both pulp fibre and wood flour with commercial polyhydroxyalkanoate polymer. The material properties were all comparable with those of commercial wood plastic composites based on polyolefins, with the exception of elongation at break (and thus toughness), which needs to be increased. Processing is critical, with voids being formed under a range of conditions such as excessive shear, excessive pressure in the barrel leading to too much expansion post die and residual water in vapour form. However, with careful management, the void content is reduced to less than 2% overall. Engagement with a range of end-users, both domestic and international, has been progressed, with sample materials requested by Dart Containers in the US, and a large-scale pilot demonstration was completed. To date one paper has been published, one submitted, three more are ready for submission (under review by industrial partners), and a further five are in draft form. A postdoctoral research fellow (Dr Luigi Vandi) will start further work on novel formulations in July.

Collaborators

- UQ Bronwyn Laycock (Dow Centre), Steven Pratt, Paul Lant, Luigi Vandi (Chem Eng)
- Industry Partner: Norske Skog, Veolia (AnoxKaldnes)

Key outcomes

Norske Skog supported a second Linkage application in December as a way to further this work and continue the engagement.



Tools for assessing the sustainability of mega-scale system transformation (e.g. food, energy etc.)

Novel environmental datasets are being coupled with a global economic model, to explore new ways of quantifying and interpreting the sustainability of large-scale technological and economic change. The environmental scope is aligned with the 'Planetary Boundaries' concept, providing a focus on specific environmental challenges of planetary scale importance. Furthermore, the suggested planetary-scale limits for each environmental issue can be used to benchmark the scale of change under consideration, providing more meaningful interpretation of the urgency and/or effectiveness of proposals.

The first project output will examine whether national-level governance structures alleviate the global nitrogen pollution challenge, or just shift burdens from developed countries to poorer regions. The integration of Greenhouse Gas (GHG) emissions datasets is also underway, complementary to other Dow Centre initiatives focussed on energy systems transformation.

The project team is currently scoping a more substantial analysis of burden shifting in the global food system, covering the issues of nutrient pollution, GHG emissions, water use and land use. As the global food system grows and transforms substantially over the 21st century, it will become an increasingly important component of solutions to sustainability challenges. As well as being an area of strategic interest to the UQ Global Change Institute, it will provide the Dow Centre an opportunity to review whether there is potential for engineering innovation in food systems to deliver substantial sustainability benefits.

Collaborators

- Global Change Institute, UQ
- Centre for Integrated Sustainability Analysis, University of Sydney

The next generation.

TEACHING - SUPERVISING - MENTORING

DOW CENTRE SUPPORTING THE BE/ME PROGRAM

Supporting a new generation of thinkers

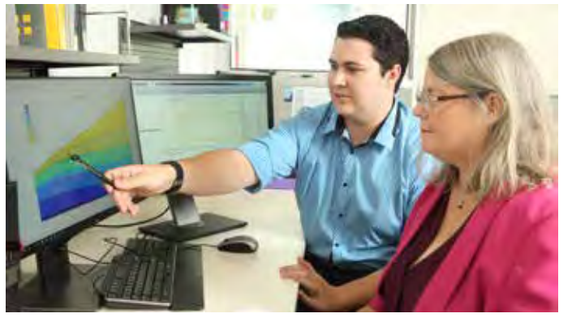
Director Chris Greig has long championed innovation as the most meaningful way to address complex problems. In 2011, after a 26 year career in industry, he joined the University to share his experience with the academic and student community.

A key element of the Dow Centre's core purpose is to help equip a new generation of thinkers with the capacity to contribute to the significant challenges to the ongoing sustainability of many industry sectors. The issues are complex, transdisciplinary and subject to rapid change. Such challenges range from the need to transition to low-carbon production, community acceptance risks, regulatory change and geopolitical change. 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 more sustainable systems in this ever changing environment.

As a Centre within the School of Chemical Engineering, in 2016 the Dow Centre supported the School's BE/ME program. The program which combines the Bachelor and Master of Engineering programs into one five year degree, allows for a six month placement within an Industry or Research environment. The aim of these 'internships' is to equip students with the experience and skills that arise from working in multidisciplinary teams across fields. The Dow Centre financially supported and/or hosted three internships within the Centre and afterwards asked the students to evaluate their experiences.

Student perspectives



Phillip Raven

Phil was part of the 'Next generation fertilizers' project, mentored by Dr Bronwyn Laycock.

This project involved producing fertiliser pellets from biodegradable waste materials with an emphasis on controlling the release rate of the nutrients contained within the pellets so as to better match the nutrient uptake requirements of the plants to which they are applied.

What are the most important skills you learned at the Dow Centre?
Time management, working in teams, self-directed learning, laboratory skills, general research skills.

How did this influence your ideas about the 'art of research' and innovation?
This placement showed me that research is a very interesting career opportunity and is incredibly important as it influences everything that industry does.

What was your highlight?
My highlight was when I made the first pellets in the pelletiser and was able to hold the creation that I had spent so much time designing.

Anything else you would like to add? Suggestions for future BE/ME students and mentors?
For the students, don't think of a research placement as a fall back for if you don't get an industry placement or as less desirable than an industry placement. The opportunities for you to learn and grow are just as prevalent in a research organisation as they are in industry.

For the mentors: don't be afraid to let your student take charge of their placement. Taking a step back to see where the student goes greatly improves their ability to learn on their own which is incredibly important and something my supervisor got right.

Alexandru Beltu

Alexandru undertook the project 'Energy Systems Modelling' under the supervision of Dr Joe Lane and Dr Simon Smart.

The scope of the project involved modelling the Australian Energy Grid. The grid comprised of numerous energy sources such as coal, gas, wind, solar, hydro and biomass as well as transmission lines to the demand locations.

What are the most important skills you learned at the Dow Centre?
The skills exercised in this project were primarily computational and data management in nature, which are extremely valuable skills in this data driven world and can be applied across any employment domain.

How did this influence your ideas about the 'art of research' and innovation?
I realised that in research it can be very challenging to stay on track towards a productive outcome and that any long term decision must be considered very carefully.

What was your highlight?
My highlight involved flying to Sydney for a week to work at the University of Sydney which was a partner university in this project. I really enjoyed meeting the people in Sydney and being exposed to the research they do.

Anything else you would like to add? Suggestions for future BE/ME students and mentors?
The Dow Centre was an exciting place to work. They have some very interesting projects focused on energy that you may not otherwise encounter in industry. So if you would like to get some more exposure to energy before you graduate, the Dow Centre has plenty of such projects to pick from.

03
TEACHING & LEARNING

Keeling Chan

Keeling was involved in two projects at the Centre, mentored by Dr Simon Smart.

Project 1: An economic offset for CCS; arbitrage of grid electricity within CCS pipelines and Project 2: An economic survey of promising-clean hydrogen production costs throughout literature.

Project 1 involved, first, researching the different current and promising hydrogen production technologies throughout literature and then populating a table with the different costs that are being reported. The motivation was that these costs can vary significantly and it is difficult to perform comparisons otherwise due to the large number of assumptions within each study.

Project 2 looked at a concept to improve the economics of CCS through energy storage. The concept was to store energy by compressing CO_2 with off-peak electricity and to expand this during times of peal electricity, for peak shaving.

What are the most important skills you learned at the Dow Centre?
Being my first work experience, this gave me some valuable insight into this field. I had opportunities to develop engineering and project skills, such as with techno-economic models. Working at the Dow Centre also gave me great opportunities to develop professional attributes, such as communication skills and proactive learning

How did this influence your ideas about the 'art of research' and innovation?
I have a better appreciation after working in this space. It's challenging and intellectually stimulating work that the people at the Dow Centre really care about. For me, I think it's really interesting because breakthroughs in innovation will feature heavily in any long-term (global) sustainability scenario.

What was your highlight?
In terms of the project work, I didn't really have any one highlight. I would say being able to engage in work with other people that were interactive and passionate made the projects much more enjoyable to work on.

Anything else you would like to add? Suggestions for future BE/ME students and mentors?
The Dow Centre is a really special place to work. I think the way they facilitate internal and external engagement makes for a friendly environment and much more enjoyable work. For me, I really felt at my best when I had opportunities to connect and collaborate with people to scope and discuss ideas and when I had some direction or some set tasks to work towards and follow.

DOW CENTRE SUPPORTING YOUNG RESEARCHERS

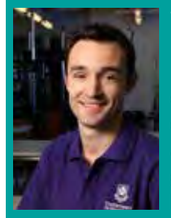
The good, the bad and the ugly: a seminar by Dr Howard Fong

Howard is one of the Dow Centre's US based consultants. He has had a long career with Shell where he ran a unit specializing in the techno-economic assessment of new technologies.

During a visit to the Dow Centre in October , Howard gave a seminar titled: *The good, the bad and the ugly, anatomy of a real-life project*. The seminar recalled the journey of a major chemical project from the ideation stage to commercialization. The focus was on the joy of capturing opportunities, the pain of falling into pitfalls and the important lessons to be learned. The Dow Centre's invitation list was aimed specifically at Early Career Researchers (ECR) and Research Higher Degree (RHD) students from Engineering, of whom approximately 60 attended.

Immediately after the event, there was a networking opportunity where audience members could catch up with Howard. A consultation workshop in which interested RHD students and ECR's were offered the opportunity to meet with Howard and discuss ways to turn their own idea or research into a business, was held the next day.

Dr Luigi Vandi reports on his 'one on one' with Dr Fong



Through the consulting workshop, I had the opportunity to meet with Dr Howard Fong for a one-on-one discussion on my project. My work, conducted within Dr Bronwyn Laycock and Dr Steven Pratt's research group, is to develop fully sustainable biocomposites by combining wood and a novel biopolymer known as PHA (polyhydroxyalkanoates). Since PHAs are produced microbiologically, our composite materials have the unique advantage of being 100% biosourced, and truly biodegradable in both a soil and marine environment at their end-of-life. However, despite demonstrating attractive mechanical properties and unprecedented life cycle benefits, the main challenge that limits their application is the rival petroleum-based polymer market, which is highly driven by low cost materials such as PE and PP.

My exchange with Dr Fong on this topic was very beneficial as he reminded me of the importance to target markets, where greener solutions offered by our material could improve a company's worldwide sustainability image. He also gave particular advice on how to find niche market applications where specific properties of Wood-PHA Composites, are currently not achievable with conventional materials. Today our group has made significant progress on material developments, successfully engaged with potential end users, and gained a more thorough understanding of current markets and applications.

STUDENT INNOVATION INITIATIVES: SISCA

In 2016 the existing SISCA competition was complemented with the Dow Centre Sustainable Engineering Innovation Start-up Program (SEIS). SISCA awards a first prize of $12,500 in cash. In addition a $12,500 Dow Centre Business Proposition Grant is offered to be reinvested into the project/business.

In previous years, several teams made submissions to the competition that were based on a good idea, but lacked the depth needed to find a place in our finals. In order to encourage such teams the Dow Centre opened a second stream where teams can compete for one of ten 'Early Concept' Grants. A concept project is eligible to be awarded $2,500 of funding which needs to be invested into further developing the project. The Dow Centre will help find suitable lab space if required and will provide informal mentoring. In 2016 seven teams received an Early Concept grant. It is hoped that these grants will lead to future submissions for the main SISCA prize.

SISCA 1st Prize Winner, HOME^3

In 2015 the HOME^3 team participated in SISCA and won the runner-up prize of $2,500, which was re-invested into the project. This obviously paid off with a well-deserved first place in the 2016 competition.

Essentially their product it is a low cost IKEA-type permanent housing solution: a flat packed panelling system that can be easily transported and assembled on location by non-specialist labour. It consists of three components: connectors, tubes and panels. The tubes twist into the connectors, creating a steel frame for the panels to slot into. An owner could start with only the base package for a small unit and add on to this when circumstances require and/or allow it. (POWER^3, a subproject, was awarded an Early Concept Grant to develop a cheap energy system for the unit.)

The multidisciplinary HOME^3 team formed as part of UQ Civil Engineering's extra-curricular ICARUS programme (which also sprouted TeeZee, the 2015 SISCA winner). The team includes a physicist, a commerce student and chemical, civil and electrical and software engineers. Currently the team is testing their prototypes and plans to kick-start its business.

Team leader Mr David Nelson said: the team believes that SISCA acted as a crucible allowing refinement of ideas, team strengthening and motivation to construct business plans and prototypes. The feedback provided the validation needed at each step of development". And "without SISCA, HOME^3 would never have been a reality".

Mr Nelson also explained how in 2014 he submitted an idea that did not make it to the finals. In a follow up conversation, the Dow Centre's then Director provided feedback and advice. Mr Nelson told us: "I learnt a lot from that quick call and it dispelled misunderstandings I had for why I had been rejected. That feedback was very valuable".

HOME^3 Prototype

Early Concept Grants

Early Concept awardees were:

- *Innovo – drones equipped with smart sensors to deploy in farming and enhance farming performance.
- *Movus – a small wind turbine to generate power for a FitMachine. The FitMachine is a sensor solution for monitoring equipment health of industrial rotating machinery, which Movus is currently piloting.
- The Deployable Shelter – a low cost, lightweight, easy to assemble prefabricated two-layer house that will provide more comfort to victims of disasters.
- Hao Cellulose – cellulose-derived carbon electrodes for supercapacitors.
- Life.Sorted – a food storage and dispensing system aimed at reducing packaging.
- Power^3 – low cost energy supply for HOME^3 units
- Solar Broadband – a system of solar photovoltaic modules to receive broadband data transmissions.

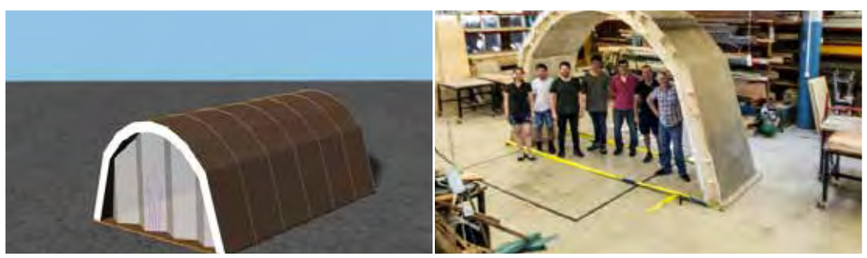
*Innovo and Movus were runners up in the SISCA main prize competition after HOME^3.

Mr Yousef Al_Qaryouti is the spokesperson for The Deployable Shelter. He provided the following feedback on their experience in the competition:

"The SISCA competition was a great chance for us to develop our pitching skills and to win funds to develop our business idea. We are now finishing the design concept of the prefabricated house and have built one of its parts to test the concept. It worked successfully and we moved on to constructing the other parts.

Developing our project gives us a chance to gain insight and form judgement on its feasibility and application as a prefabricated resilient infrastructure. Through the work the team is developing expertise across a broad range of investigation methods, materials and fabrication methods."

Saphira Rekker from Life.Sorted added: "The initial support provided by the Dow Centre is a significant vote of confidence that has encouraged us to make our business a reality".

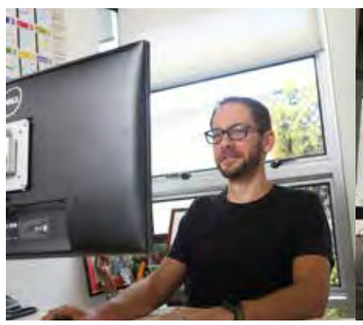


Deployable Shelter simulation and prototype

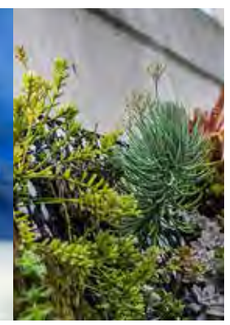
03
TEACHING AND LEARNING

The centre staff contribute to a number of courses within the Faculty of Engineering

Centre member	Role	Course
Simon Smart	Lecturer	CHEE3007, Process modelling and dynamics
Diego Lopez Schmeda	Instructor	CHEE3020, Semester 1, Process systems analysis
Sara Zeinal Zadeh	Tutor	MECH3600, Engineering management and communication
Simon Smart	Course coordinator and lecturer	ENGY4000, Semester 1, Energy systems
Brett Parkinson	Tutor	CHEE4009, Semester 1, Transport phenomena
Sara Zeinal Zadeh	Tutor	MECH4103, Engineering asset management
Chris Greig	Course coordinator and lecturer	ENGG4900, Semester 2, Professional practice in the business environment
Simon Smart	Tutor	
Ben Kefford	Tutor	
Diego Schmeda Lopez	Tutor	
Simon Smart	Course coordinator and lecturer	ENGY7000, Energy principles and renewable energy
Chris Greig	Course coordinator and lecturer	ENGY7004, Investment decision making in the energy sector
Sara Zeinal Zadeh	Tutor	ENGG7601, Experimental design
Eric McFarland	Facilitator	Heterogeneous Catalysis Group (video link with UCSB)





03
TEACHING AND LEARNING

The Centre staff supervise 30 postgraduate students

Student	Supervisors	Project Title
$Mr Clement Chan (PhD)	Dr Bronwyn Laycock Dr Steven Pratt Prof Peter Halley Dr Luigi Vandi	Processing and characterisation of polyhydroxyalkanoate (PHA)-based wood plastic composites (WPCs)
$Mr Edward Jiang (PhD)	Prof Darren Martin Dr Pratheep Annamalai Dr Bronwyn Laycock	Water-based processing of spinifex nanocellulose fibrils into continuous textile fibres
$Mr Ian Levett (PhD)	Dr Bronwyn Laycock Dr Steven Pratt	Development of novel controlled release fertilizers for improved nutrient delivery efficiency
$Ms Romy Listo (PhD)	Dr Peter Westoby Prof Chris Greig	Moving beyond the tension of 'up and across' – an investigation into the practical and ethical implications of scaling community development for energy poverty interventions.
$Ms Pawarisa Luangthongkam (PhD)	Dr Steven Pratt Dr Bronwyn Laycock Prof Paul Lant	Biosynthesis of polyhydroxyalkanoates (PHAs) in methane-utilizing mixed cultures
$Mr Yuwan Malakar (PhD)	A/Prof Elske van de Fliert Prof Chris Greig	Socio cultural perspective on energy deprivation in rural India
$Mr Rhys Pirie (PhD)	Prof Susanne Schmidt Dr Richard Brackin Dr Bronwyn Laycock Dr Francois Visser	Next-generation fertilisers for nutrient stewardship
$Ms Syarifah Nuraqmar Syed Mahamud (PhD)	Dr Bronwyn Laycock Dr Steven Pratt Prof Paul Lant	Polyhydroxyalkanoate (PHBV) copolymer production using methanotrophics cultures
$Ms Sara Zeinal Zadeh (PhD)	Dr Simon Smart Dr Diego Schmeda Lopez 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
$Ms Julia Mueller (MPhil)	Dr Simon Smart Prof Eric McFarland	Active anti-fouling and defouling of membranes using electrochemical methods
$Mr Isaac Ayodeji (M Energy Studies)	Dr Simon Smart Dr Diego Schmeda Lopez	Australia's future energy mix; a case for nuclear power
$Mr You-Hsing Huang (M Eng Thesis)	Dr Simon Smart Mr Brett Parkinson	Temporary of-grid power supply for refugee camps
$Mr Caleb Dieters (4th year)	Dr Simon Smart Dr Diego Schmeda Lopez	Techno-economic comparison of unconventional bioethanol feedstocks, waste paper and paper sludge, to conventional feedstocks
$Ms Pippa Edwards (4th year)	Dr Diego Schmeda Lopez	Techno-economics of Hydrogen use for light vehicle applications (Undergraduate Thesis)
$Mr Ryan Koh (4th year)	Dr Diego Schmeda Lopez	How nuclear power fits in a carbon constrained future: A review based on cost, carbon footprint and safety
$Arsyandi Medrial (4th year)	Dr Simon Smart	Process design using forward osmosis membrane separation for fuel grade ethanol production

The Centre staff supervise 30 postgraduate students

Student	Supervisors	Project Title
$Mr Keeling Chan (BE/ME Internship)	Dr Simon Smart	1) Economic offset for CCS 2) Economic survey of promising clean hydrogen production costs throughout literature
$Mr Zac Loewenthal (BE/ ME Internship)	Dr Simon Smart	Energy systems analysis of a potential Australian nuclear industry
$Mr Phillip Raven (BE/ME Internship)	Dr Bronwyn Laycock	Next generation fertilisers
$Ms Jasmine Schiks-Du (BE/ME Internship)	Dr Bronwyn Laycock	Food waste treatment technologies
$Ms Emi Ariga (Summer Research Scholar)	Dr Ben Ballinger Mr Brett Parkinson	True cost of utility scale solar PV
$Yee Xun Chung (Summer Research Scholar)	Mrs Mojgan Tabatabaei Mr Brett Parkinson	Alternative ammonia production
*Ms Franziska Curran (PhD)	Prof Paul Lant Dr Justine Lacey Dr Simon Smart Prof Chris Greig	Informing energy projects in developing countries by leveraging lessons learnt from the water sector
*Mr Johannes Grové (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
*Mr 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
*Mr Anthony Heynen (PhD)	Prof Paul Lant Dr Simon Smart Prof Chris Greig A/Prof Srinivas Sridharan	The energy poverty nexus: understanding how poverty and energy are interconnected in the developing world
*Ms Danielle Lester (PhD)	Prof Jose Torrero Cullen Prof Chris Greig Dr Maureen Hassall	Causal analysis of major project success and failure and implications for educating engineers as project leaders
*Mr Andrew Pascale (PhD)	Prof Paul Lant Dr Simon Smart Prof Chris Greig	The energy poverty nexus: helping billions of people out of impoverishment with reliable affordable and sustainable energy systems.
*Mr Thomas Reddell (PhD)	Dr Ananthanarayanan Veeraragavan Dr Simon Smart	Dynamic modelling of a supercritical carbon dioxide cycle
*Mr Gregory Siemon (PhD)	Dr Simon Smart Prof Ian Cameron	Enterprise-wide optimisation in steelmaking
*Mr Alexandru Beltu (BE/ME Internship)	Dr Simon Smart Dr Joe Lane	Energy systems optimization

Please note. Prof Chris Greig, Dr Bronwyn Laycock and Dr Simon Smart have partial appointments at the Dow Centre. Some of their students' subjects are therefore not or only partially related to Dow Centre projects. We have used the following indicators:

$ Dow Centre Students or students whose research topic is part of a Dow Centre Project.

* Students whose subject is related to Dow Centre projects. Most of these students belong to the Energy Poverty Group.

Engagement activities

ENGAGEMENT - OUTREACH - COLLABORATION

TeraWatts, teraGrams, teralitres

Initiated in 2014, the New Frontiers Workshop is a joint initiative of UQ's Dow Centre and the University of California, Santa Barbara, Dow Materials Institute. The objective is to bring together forward thinking engineers and scientists from industry and academia to "talk, argue, speculate and dream a little about what might be possible if only we could….".

The 2016 edition of the New Frontiers Workshop focused on the challenges and options for the future of food, sustainable feedstocks, and the social, governmental and economic barriers for environmentally and economically sustainable chemicals. The Dow Centre supported six delegates from UQ to attend the workshop. The central plan of the workshop was to engage in provocative forward-thinking to processes and problems that are not presently part of the R&D focus in industry, but might be there in the future if major fundamental problems in chemical and material science and engineering were solved or barriers removed. The workshop as a whole, was a thought provoking experience, engaging in discussions with leaders and top young graduates around global issues where global solutions require a collective, multi-disciplinary approach.

Solutions for minimal and zero liquid discharge using specialty membranes from Dow

A technical seminar, organised by Dow Energy and Water Solutions with assistance from the Dow Centre, was held at St Leo's College on the UQ Campus in August. The workshop introduced specialty reverse osmosis membranes and chemicals to the industrial water, waste water and energy engineering community in Queensland. Among the delegates were three Dow Centre team members. Centre Director Chris Greig opened the workshop with a word of welcome. Immediately following the workshop the Dow Centre hosted a well-attended networking event on the Dow Centre's outdoor deck where delegates of the workshop could mix and chat with many researchers from UQ's School of Chemical Engineering and Dow Centre Staff.

Specialty membranes workshop at St Leo's College

05
ENGAGEMENT ACTIVITIES

Gas Fermentation Workshop, Heron Island

The aim of the workshop was to build a gas fermentation initiative in Australasia and to introduce the gas fermentation community to one another in order to establish relationships on which future collaborations can be built. Key aspects of C1-fermentation, commercialisation, physiology and systems metabolic engineering were explored. The workshop attracted some of the foremost international experts in the space of gas fermentation and served as an effective vehicle for establishing the current state-of-the-art and the potential for future research, funding, and collaboration in this space.

The workshop, formed the final part of a larger project on Natural Gas Fermentation which was partly sponsored through the Dow Centre's Pitching Program (see also Annual Reports of 2014 and 2015).

Natural Gas Fermentation Workshop on Heron Island. Dr Bronwyn Laycock 3rd from left in front row

Representatives from the following organisations visited the Centre

- China, Tsinghua University
- Germany, Potsdam Institute for Climate Impact Research
- USA, Andlinger Centre for Energy and Environment, Princeton
- USA, Carnegie Mellon University
- USA, Manhattan Institute
- USA, Princeton Environmental Institute, Princeton University
- USA, University of California, Santa Barbara

Centre members visited the following institutes/companies

- Adelaide, 9th International Membrane Science and Technology Conference, presentation
- *Brisbane, McDonnell International Scholars Academy 6th International Symposium, keynote presentation
- Boyer, Norske Skog, Tasmania, project review
- Canberra, The Circular Economy to Food Security, conference attendance
- *Canberra, Low Emissions Technologies for Fossil Fuels Leadership Roundtable, invited participant
- *Canberra, Minerals Council Australia, Carbon Capture and Storage project meeting
- Heron Island, Natural Gas Fermentation Workshop, keynote speaker
- Heron Island, Next Generation Fertilizers Conference, presentation
- Melbourne, Dow Chemical (Australia), meet and greet, future Dow Centre strategy
- *Newcastle, NSW Mining Health, Safety, Environment and Community Conference, keynote speaker
- *Perth, Curtin University, Energy Research Review
- Sydney, Manufacturing for Water Workshop, Water NSW, scoping workshop
- Sydney, University of Sydney, project discussion
- Sydney, Thales Headquarters, project review

** Visits are in association with the UQ Energy Initiative*

05
ENGAGEMENT ACTIVITIES

Centre members visited the following institutes/companies

- Brazil, Porto Alegre, Universidade Federal do Rio Grande do Sul (UFRGS), invited presentation
- Brazil, Porto Alegre, Universidade do Vale do Rio dos Sinos (Unisinos), invited presentation
- China, Beijing, National Institute of Clean and Low-Carbon Energy (NICE), meetings
- China, Guangzhou, Guangdong Sugarcane Industry Research Institute, invited Presentation
- China, Kunming, Yuntianhua Group, invited presentation
- China, Dow Chemical (Shanghai), meet and greet, collaboration options
- China, Dow Chemical (Shanghai), presentation and discussions
- China, Shanghai, Fudan University, meetings
- China, Shanghai, General Electric (GE), meetings
- China, Shenzen, Southern University of Science and Technology, invited presentation
- *France, Paris, International Energy Agency, conference presentation and meetings
- *India, Mumbai, Delhi, Bhubaneswar and Udaipur, project meetings with several collaborators
- *Indonesia, Jakarta, Ministry of Energy and Mineral Resources, lecturing of short course on Energy Project Financing
- Israel, Haifa and Beer Sheva, Israel Chemical Limited, site visit and project discussions
- Paraguay, Asunción, Universidad Paraguayo Alemana, invited presentation
- *UK, London, BP Princeton Carbon Mitigation Conference, presentation and meetings
- USA, Berkeley, University of California, Berkeley, presentation
- USA, Houston, Shell Westhollow, discussion with potential industry partners
- USA Pasadena, California Institute of Technology, Presentation
- *USA, Princeton, Princeton University, project meetings
- USA, Santa Barbara, University of California, Santa Barbara, (Dow Centre supported delegation of 6) New Frontiers Workshop, attendance and presentations
- USA, Santa Barbara, University of California, Santa Barbara, academic visit
- *USA, St Louis, McDonnell Academy Symposium, organisation discussions

05 ENGAGEMENT ACTIVITIES

Collaborating organisations

The Dow Centre has strong connections with other research groups at the University of Queensland, not only in the School of Chemical Engineering of which it is part, but also with researchers in other institutes and schools. We actively collaborate with researchers in of eight of them, especially with the researchers and students of the UQ Energy Initiative to whom we are now closely affiliated.

The University of Queensland collaboration partners

- Advanced Water Management Centre, Prof Damien Batstone
- Australian Institute of Bioengineering and Nanotechnology, Prof Darren Martin et al., Esteban Marcellin Saldano et al.
- Centre for Coal Seam Gas, Prof Andrew Garnett
- Global Change Institute, Prof Karen Hussey
- School of Agriculture and Food Science, Prof Susanne Schmidt
- School of Chemistry and Molecular Biosciences, Prof Craig Williams
- School of Information Technology and Electrical Engineering, Prof Tapan Saha et al.
- UQ Energy Initiative, Prof Peta Ashworth et al.

Australian collaboration partners

- ACA Low Emission Technologies Ltd (ACALET), Mr Greg Evans
- Advanced Manufacturing Industry Growth Centre, Dr Jens Goennemann
- ANLEC R&D, Dr Noel Simmento
- Australian Meat Processing Council
- Chevron Australia Pty Ltd, Mr John Torkington
- Commonwealth Department of Industry and Science, Mr Josh Cosgrove
- CSIRO, Dr David Harris
- Energy Pipelines CRC, Mr David Norman
- Energy Policy Institute of Australia, Mr Robert Pritchard
- INPEX, Mr Reinoud Bloc
- Global CCS Institute, Mr Alex Zapantis
- Manildra Starch, Mr Mark Baczynski
- Minerals Council of Australia, Mr Brendan Pearson
- Mitsubishi Australia Ltd, Mr Baden Firth
- Monash University, A/ Prof Srinivas Sridharan
- National Energy Resources Australian Industry Growth Centre, Mr Ken Fitzpatrick
- Neocology Pty Ltd, Mr Michael Wilson
- Norske Skog Boyer, Dr Des Richardson
- NSW Minerals Council, Mr Greg Sullivan

05 ENGAGEMENT ACTIVITIES

Australian collaboration partners, cont.

- Office of the Chief Scientist, Dr Alan Finkel
- Printed Energy Pty Ltd, Mr Roger Whitby
- Qld Department of Agriculture and Fisheries, Dr Matt Redding and Dr Chris Pratt
- Qld Department of Energy and Water Supplies, Dr Paul Simshauser
- QUT Bluebox, Mr Callum Hickey
- Shell Brisbane, Dr Jack Barnes
- Swinburne University, Prof Bronwyn Fox
- The University of New South Wales, Prof Ian Gibson
- University of Sydney, Prof Manfred Lenzen
- Veolia (AnoxKaldnes), Dr Alan Werker

International collaboration partners

- BHP Billiton Ltd, Dr Sharna Glover
- BP, Mr Gardner Hill
- Carnegie Mellon, Prof Mitchell Small and Dr Gabrielle Wong-Parodi
- Delft University of Technology, Prof Freek Kapteijn
- Dow Chemical (Midlands), Dr Chris Derstine and Dr Michael Mills
- Foundation for Ecological Security (India), Dr Jagdeesh Rao
- General Electric Company, Mr Kirby Anderson
- Georgia Institute of Technology, Prof Sankar Nair
- Glencore, Mr Mick Buffier
- IIT Bombay, Prof Rangan Banerjee
- Institut Européen des Membranes - Université de Montpellier, Dr Anne Julbe
- International Energy Agency, Dr Fatih Birol
- International Institute for Applied Systems Analysis (IIASA), Dr Fabian Wagner
- Israel Chemical Limited, Dr Reinhard Effenberger and Dr Joseph Zilberman
- Kuwait Institute of Scientific Research, Dr Firas Rasoul
- Potsdam Institute / IPCC, Prof Ottmar Edenhofer
- Princeton University, Prof Robert Socolow and Prof Eric Larson
- StarCore Nuclear, Mr Ad Dabney
- Tata Institute for Social Sciences, Prof Lakshmi Lingham
- The Ohio State University, Prof Henk Verweij
- Tsinghua University, Prof Li Zheng
- University of California, Santa Barbara, Prof Horia Metiu

05
ACTIVITY OVERVIEW

INTERNAL SEMINARS

In 2016, 12 guest speakers presented their work during the weekly team meetings.

PARTNERS

In 2016 the Dow Centre collaborated with
8 UQ Institutes, Schools and Groups
29 Australia based organisations
22 Organisations outside Australia

PUBLICATIONS*

13 PEER-REVIEWED PUBLICATIONS RELATED TO SUSTAINABLE ENERGY & MATERIALS, 1 REPORT

LEAD AUTHORSHIP OF PUBLIC POLICY REPORT A ROADMAP FOR CCS IN AUSTRALIA

PUBLIC INTEREST REPORT RESPONDING TO NSW POLICY CLIMATE CHANGE FRAMEWORK

* IN AFFILIATION WITH UQ ENERGY INITIATIVE

ENGAGEMENT*

3 UQ ENERGY EXCHANGE EVENTS AIMED AT REPRESENTATIVES FROM INDUSTRY FEATURING GLOBAL LEADERS FROM IEA, IPCC AND PRINCETON.

10 UQ ENERGY EXPRESS PUBLIC SEMINARS

2 STATE LIBRARY MEET THE PUBLIC - ON ENERGY POLICY

* IN AFFILIATION WITH UQ ENERGY INITIATIVE

05
ACTIVITY OVERVIEW

RESEARCH TRAINING

The Centre staff currently supervise 31 students

RESEARCH PROJECTS

The Centre established three Flagship Projects.

BRIEFINGS & EVENTS

3 ADVISORY BOARD MEETINGS

6 WORKSHOPS ORGANISED/ SUPPORTED BY CENTRE

6 NETWORKING EVENTS ORGANISED BY CENTRE

INNOVATION

RECORD NUMBER OF NOMINATIONS FOR THE SUSTAINABLE INNOVATION STUDENT CHALLENGE AWARDS (SISCA)

ESTABLISHED A NEW DOW CENTRE SUSTAINABLE ENGINEERING INNOVATION START-UP PROGRAM (SEIS) FOR STUDENT ENTREPRENEURS

06 PUBLICATIONS

Journals

Chan C., Vandi LJ., Pratt S., Halley P., Richardson D., Werker A., Laycock B. *Processing and characterisation of polyhydroxyalkanoate (PHA)-based wood plastic composites: effect of non-reactive additives*. Appita Journal, 2016, 69(4): 352-260

Covey G., Laycock B., O'Shea, M., Vuong K. *Maximising value from biomass*. Conference Technical Papers, p37-34, (Oral presentation by Dr Covey), Fibre Value Chain Conference and Expo 2016, 12-14 October 2016, Rotorua, New Zealand

Golev A., Schmeda-Lopez DR., Smart SK., Corder GD, McFarland EW. *Where next on e-waste in Australia?* Waste Management, 2016, 58, 348-358

Levett I., Birkett G., Davies N., Bell A., Langford Z., Laycock B., Lant P., Pratt, S. *Techno-economic assessment of poly-3-hydroxybutyrate (PHB) production from methane – the case for thermophilic bioprocessing*. Journal of Environmental Chemical Engineering, 2016, 4(4), Pt A: 3724–3733

Marcellin E., Behrendorff JB., Nagaraju S., DeTissera S., Segovia S., Palfreyman R., Daniell J., Licona-Cassani C., Quek L., Speight R., Hodson M., Simpson S., Mitchell, W., Köpke M, Nielsen LK. *Low carbon fuels and commodity chemicals from waste gases - Systematic approach to understand energy metabolism in a model acetogen*. Green Chemistry, 2016, 18(10) 3020-3028 (IF=8.5)

Mubeen S., Jun YS., Lee J.,McFarland EW. *Solid suspension flow batteries using Earth abundant materials*. ACS Applied Materials and Interfaces, 2016, Vol 8, Issue 3, 1759-1765, doi 10.102/acsami.5b09515

Parkinson B., Greig C., McFarland E., Smart S. T*echno-economic analysis of a process for CO_2-free coproduction of iron and hydrocarbon chemical products*. Chemical Engineering Journal, online December 2016, in print April 2017, Vol 313, 136-143

Shaner MR., Atwater HA., Lewis NS., McFarland EW. *A comparative techno-economic analysis of renewable hydrogen production using solar energy*. Energy and Environmental Science, 2016, 9, 2354-2371

Strong PJ., Laycock B., Mahamud SNS., Jensen PD., Lant PA., Tyson G, Pratt S. *The opportunity for high-performance biomaterials from methane, microorganisms*. 2016, 4(1), 11

Upham DC., Snodgrass ZR., Tabatabaei Zavareh M., McConnaughy TB., Gordon MJ., Metiu H., McFarland EW. *Molten salt chemical looping for reactive separation of HBr in a halogen based natural gas conversion process*. Chemical Engineering Science, on line November 2016, in print March 2017, Vol 160, 245-253

Reports

Greig C., Bongers G., Stott C., Byrom S. *Energy security and prosperity in Australia, a roadmap for carbon capture and storage*. The University of Queensland, online December 2016, formally launched January 2017, ISBN 978-1-74272-175-0

McConnaughy TB., Tabatabaei M., Grosso P., Fong H., Marcellin E., McFarland E. *A techno-economic analysis of advanced methane conversion technologies for small scale applications.* (confidential)

Affiliated publications: UQ Energy Poverty Group

Grové J., Lant PA., Greig CR., Smart, S. *Is MSW derived DME a viable clean cooking fuel in Kolkata, India?* Proceedings of the 6th International Symposium on Energy from Biomass and Waste, Venice, November 2016

Herington MJ., van de Fliert E., Smart S., Greig C., Lant, P. *Rural energy planning remains out-of-step with contemporary paradigms of energy access and development*. Renewable and Sustainable Energy Reviews, online October 2016, in print January 2017, Vol 67, 1412-1419

Herington MJ., Malakar J. *Who is energy poor? Revisiting energy (in)security in the case of Nepal.* Energy Research and Social Science, online July 2016, in print November 2016, Vol 21, 49-53

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