DOW CENTRE FOR SUSTAINABLE ENGINEERING INNOVATION

ANNUAL REPORT 2017

THE UNIVERSITY OF QUEENSLAND
AUSTRALIA

Create change

dowcsei.uq.edu.au

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Vice-Chancellor's message

"The Dow Centre has not faltered from its mission to foster, identify, and facilitate innovations in economically and environmentally sustainable processes associated with the production and use of energy, water, food and chemicals."

On behalf of the Dow Centre Advisory Board, it gives me great pleasure to introduce the 2017 Dow Centre for Sustainable Engineering Innovation Annual Report.

The University of Queensland has positioned itself as a champion of knowledge leadership for a better world; however, given the pace of change in the world, this simply stated aim can often be difficult to accomplish. Rising population, increasing living standards across Asia, and the impact of climate change all present significant challenges – as well as wonderful opportunities. Creating positive change in the face of such challenges is increasingly achievable as we work within the collaborative and innovative research structures of UQ, supporting engineering innovation and contributing towards global prosperity and a sustainable future.

In the five years since the Dow Chemical Company's very generous donation to establish the Dow Centre, the Centre has not faltered from its mission to foster, identify, and facilitate innovations in economically and environmentally sustainable processes associated with the production and use of energy, water, food and chemicals.

With the refocusing of its three flagship research programs in 2016 – Rapid Switch, increasing the sustainability of methane utilisation, and low CO_2 iron production – the Dow Centre is again delivering significant research outcomes. These will continue to establish new ways of thinking about the transition to a more sustainable world with a focus on sustainable technological development which is environmentally and socially acceptable, economically competitive and scalable.

The particular highlights of 2017 – including the expansion of Rapid Switch to collaborate with several world-class university partners, securing almost A$3 million in Commonwealth- and State-funded research grants, and advancing links with industry partners in a number of key research areas – illustrate the Centre's relevance in an ever changing science and innovation sector that demands agility.

The Dow Centre continues to help The University of Queensland to create change. In 2017, some 36 PhD students worked on key projects that will both inspire their individual careers and bring about advances to better the world in which we all live. Dow Centre leaders also coordinated and taught courses to more than 1000 undergraduate and Master's level engineering students. The Dow Centre's ongoing commitment to 'The Next Generation' helped equip students with professional practice skills, the capacity to innovate effectively, and an appreciation of the beneficial outcomes from working in multidisciplinary teams.

On behalf of the Advisory Board, I congratulate Professor Chris Greig on guiding the Dow Centre. His leadership continues to focus on exciting projects that will 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 2017. Finally, I thank the Dow Chemical Company for its continued generous investment and support, which enabled the Dow Centre to thrive in 2017.

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

Director’s report

“The Dow Centre is committed to delivering solutions to globally significant challenges by generating new knowledge. Our approach is to work only on systems which have the potential to have significant impact on sustainability and the economy. ”

Capitalising on our Strategy

In 2016, the Dow Centre sharpened its focus to three flagship programs through which we could make an original and significant contribution to moving the needle on global sustainability - in the areas of production and utilisation of energy and materials. In the screening process we ranked opportunities by: (a) their potential impact on global sustainability and our regional economy; and (b) the potential for the Dow Centre to make a significant contribution. This led to our three flagship programs:

Rapid Switch – an international network originated at the Dow Centre which seeks to identify, anticipate and communicate industrial, regulatory and social bottlenecks and constraints that might impact the pace of decarbonisation of the global economy. The intended impact is better informed public-policy and private investment decision-making.

Low-CO_2 Iron-Making – a new process in which iron ore is reduced using natural gas in molten salts and metals. The process yields solid iron, solid carbon and no CO_2. The intended impact is a next generation steel making process which does not generate greenhouse gas emissions.

Low-CO_2 Hydrogen and Fuels – new processes which produce hydrogen and or syngas by pyrolysing methane in molten salts and metals without CO_2 production. The intended impact is a suite of future fuels and chemicals processes which generates low greenhouse gas emissions.

Each of these projects achieved good progress throughout 2017 and we enter 2018 with several significant outcomes emerging.

The Rapid Switch project has developed strong partnerships with Princeton University and Carnegie Melon University and we have new partnerships starting in India, with IIT-Mumbai and Ashoka Trust for Energy and Environment, and in China with Tsinghua University and the National Institute for Clean and Low Carbon Energy.

In the case of our low-CO_2 iron project, we achieved proof-of-concept of individual unit processes and completed a comprehensive process model and techno-economic analysis. This process has now achieved (Technology Readiness Level) TRL-4 and looks to be substantially more competitive than alternatives for decarbonising the steel industry such as carbon capture and storage.

Our low-CO_2 hydrogen and fuels project, has shown a number of emerging process opportunities which are at TRL-2 to TRL-3, ranging from the production of pure hydrogen from natural gas and bio- (land-fill)-gas, to dry reforming of high-CO_2 natural gas, with the potential to monetise significant natural gas resources which today are unlikely to be developed.

Expanding our Horizon

Whilst the major focus and investment has been in our flagship projects we continue to explore for new opportunities which satisfy our strategic criteria of potential impact on both global sustainability and our regional economy, and the potential for the Dow Centre to make a significant contribution. In 2017, three promising projects emerged – Next Generation Fertilisers, Printed Energy Devices, and Energy Poverty Reduction.

Next Generation Fertilisers is a collaborative project with UQ’s School of Agriculture and Food Sciences along with the Queensland Government and industry to improve the efficiency of fertiliser use in agriculture. The project is using materials science and microbiology in an effort to reduce land degradation and nutrient run-off. These issues are significant for agricultural productivity and ocean health world-wide including here in Queensland where the health of the Great Barrier Reef is at stake.

The project achieved success in the most recent Advance Queensland Innovation Partnerships funding round raising $680,000.

Printed Energy Devices is a collaborative project with UQ’s AIBN, UNSW and Printed Energy Pty Ltd to develop and commercialise thin flexible printed batteries. These will have the ability to revolutionize the powering of products such as disposable healthcare devices, sensors and wearable electronic devices. The batteries will ultimately be printed in a roll-to-roll process like a newspaper, providing significant flexibility in the way they can be incorporated into every day products.

The project successfully raised $4 million from Printed Energy and the Commonwealth Government through the CRC-Projects grant scheme.

Energy and Poverty is a collaborative program with a range of schools across UQ to address the challenge of providing affordable, reliable and sustainable energy services to the energy impoverished. Focused on India the program is also active in Nepal, Papua New Guinea and Southern Africa. The Dow Centre along with the current director provided significant seed funding to help establish this group in 2014. Since that time, the group has enrolled 11 PhD students (three completed to date) working across multiple disciplines and all of whom have undertaken substantial field work in the priority countries.

The Dow Centre plans to increase its participation in this exciting project during the coming years.

Aligning with UQ's Strategic Objectives

In early 2018, UQ released its Strategic Plan for 2018 – 2021. The Dow Centre's activities remain aligned with UQ's long-term strategic objectives and we will seek to strengthen that alignment moving forward.

1. *Transforming students into game-changing graduates who make outstanding contributions and address complex issues with a global perspective.*

The Dow Centre continued to make a significant contribution to educating students in the faculty of Engineering Architecture and IT, with several of our team members leading a range of important courses covering professional practice, business, ethics, innovation, energy systems, and sustainability.

The Dow Centre continued to be an advocate and major contributor to building a culture of innovation and a community of entrepreneurs among UQ's undergraduate and postgraduate students. Once again we hosted the Dow Sustainable Innovation Student Challenge Awards (SISCA) attracting yet another record number of quality nominations

2. *Delivering globally significant solutions to challenges by generating new knowledge and partnered innovation.*

The Dow Centre is committed to delivering solutions to globally significant challenges by generating new knowledge. Our approach is to work only on systems with the potential to have significant impact on sustainability and the economy. The partnership between UQ and Dow provides a powerful demonstration of partnered innovation. Dow's generous gift along with the guidance provided by Dow's nominees on the Strategic Advisory Board is an exemplar for corporate philanthropic support of research, innovation and higher education.

3. *Developing a diverse community of knowledge seekers and leaders who embody a One UQ culture and use collaborative partnerships to connect and co-create.*

Though we are hosted in the School of Chemical Engineering, the Dow Centre continues to collaborate across campus including in the faculties of Science, Business Economics and Law, Humanities and Social Sciences, and Health and Behavioural Sciences along with institutes, including the Australian Institute for Bioengineering and Nanotechnology, the Sustainable Minerals Institute, the Queensland Alliance for Food and Agriculture Innovation, and the Global Change Institute. These efforts seek to mobilise the diverse capabilities and approaches to important challenges that could have a profound impact on global sustainability.

Looking Ahead

The year ahead promises to be one of the more significant for the Dow Centre. New external funding opportunities are expanding and we hope to raise significant new funding in support of all three existing flagship projects. At the same time we look forward to advancing our efforts in Energy Poverty, Next Generation Fertilisers and Printed Energy, and to building our pipeline of new opportunities.

There are however significant areas to be improved. First and foremost is gender diversity. We do benefit from significant cultural diversity with researchers coming from Australia, China, Vietnam, Britain, the United States, Italy, Nigeria and Iran, however on the gender front, we remain male dominated. We must make serious progress to address this imbalance over the coming years.

Finally, 2017 was also a watershed year for our major donor with the successful merger of Dow and DuPont. At the announcement, UQ Chemical Engineering alumnus and DowDuPont executive chairman, Andrew Liveris said, "We are extremely excited to complete this transformational merger and move forward to create three intended industry-leading, independent, publicly traded companies." The UQ Dow Centre looks forward to continuing and strengthening its relationship with the new organisation.

Key outputs 2017

Academic output

PEER REVIEWED PUBLICATIONS	SEMINARS & PRESENTATIONS	SUPERVISED STUDENTS	DOW CENTRE WORKSHOPS
18	>20	53	8

Engagement

STATE LIBRARY/ QLD MUSEUM EVENTS	PUBLIC OUTREACH EVENTS	MOVIE SCREENING
4	8	1

Industry/government impact

GOVERNMENT BRIEFINGS	MEMBERSHIPS TO INDUSTRY ASSOCIATIONS	GUEST LECTURES, PANEL SESSIONS, INTERVIEW
12	17	43

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 2017, the Board met on: 9 February, 8 June and 20 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 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 PETER HALLEY
Head, School of Chemical Engineering,The University of Queensland

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

PROFESSOR 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 that were cited 12,000 times. He has had the pleasure of supervising more than 45 PhD students who have received their doctoral degree.

LOUIS VEGA
President & Managing Director, Australia and New Zealand and Vice President Olympic & Sports Solutions, Dow Chemical Company (Dow)

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

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

Dr Weiguang Yao is the Chief Technology Officer for Asia Pacific R&D. He is responsible for 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 and on charitable not for profit boards. Most recently in his career at Dow, Mr Williams was appointed as Vice President to lead Dow's Business Development efforts in Asia Pacific, while previously he had been President of Dow in South East Asia, Australia and New Zealand, all based in Singapore. Mr Williams is a past Chairman of the Board of the Institution of Chemical Engineers (IChemE) in Australia and was a Governor and Treasurer of the American Chamber of Commerce in Singapore. He is a past President and Director of the Australian Plastics and Chemicals Industry Association (now Chemistry Australia) . Mr Williams also serves as chairman on the UQ School of Chemical Engineering Advisory Board.

Professor Chris Greig, Director

Chris Greig was the founding director of the UQ Energy Initiative and is now director of the Dow Centre for Sustainable Engineering Innovation. He is a Chemical Engineer having obtained his degree and PhD at The University of Queensland and is a Fellow of the Academy of Technological Sciences and Engineering. His career commenced with a successful start-up company that he founded while completing his PhD at UQ. He led that company for 15 years before successfully exiting through its sale in 1999. Prior to joining UQ in 2011, Chris held senior executive roles in the construction, resources and low-carbon energy sectors. He has held various other non-executive directorships with ASX listed companies, was Deputy Chairman of Gladstone Ports Corporation until 2015 and is a current director of the Energy Policy Institute of Australia.

At UQ, in addition to his substantive roles as director of the Dow Centre for Sustainable Engineering Innovation and the UQ Energy Initiative, Chris has served on the Advisory Boards for the Centre for Coal Seam Gas (Chair) and the Queensland Geothermal Energy CoE. He remains a member of the Advisory Board of the School of Chemical Engineering and co-leads the Energy Poverty Research Group.

Chris' teaching activities include course coordinator for ENGG4900 – Professional Practice in the Business Environment; and ENGY7004 - Energy Finance and Investment.

His main research interests lie in Energy Transitions, Techno-Economic Assessment of industrial processes, Energy for Development and Mega-Project Implementation.

Dr Jon Davis, Adjunct Professor

Dr Jon Davis received his PhD from the Julius Kruttschnitt Mineral Research Centre at the University of Queensland. His thesis involved the development of a method for evaluating mineral processing circuits, which lead to the establishment of an SME – which continues to this day – to sell testing equipment to industry. Jon was subsequently an Australian National Research Fellow in China, and lectured in mineral processing at the University of Queensland while conducting contract research for the mining industry. Jon then joined Rio Tinto, and worked as a project manager and research team leader before setting up, and then leading, the Energy Technology Group. Jon was a board member of a wide range of organisations in the coal use/low emissions technologies area, and was the inaugural MD – on secondment from Rio Tinto – of the Australian Low Emission Coal research centre. At the Dow Centre Jon uses his experience in Industry and Research to assist with the evaluation and/or development of newly proposed projects and future strategies, as well as mentoring younger team members in their ongoing projects.

Professor Stephen Wilson, Adjunct Professor

Professor Stephen Wilson is leading the global economic modelling component of the Rapid Switch project with the Dow Centre. In 2017, Stephen was appointed as an Adjunct Professor in the UQ Energy Initiative, developed and delivered a masters-level course on Energy Markets, Law and Policy, and delivered an Energy Express Seminar on the challenges emerging in the Australian market arising from decarbonisation goals and the future integration of high-shares of renewable energy. As part of the Rapid Switch project, Stephen made two trips to the US to work with colleagues at Princeton and Carnegie Mellon. Stephen identified a suitable global equilibrium model that can be used to accelerate the identification of countries and regions, sectors and technologies that may be relied upon for rapid rates of change. Those areas will be especially crucial for identification of industrial bottlenecks, and for practical and sustainable strategies and innovation to relieve them. Stephen helped in the successful negotiation of a collaboration providing access to the model under attractive terms to the Dow Centre and the wider Rapid Switch project.

In late 2017, Stephen was offered a full professorship at the University of Queensland, which he accepted. He is excited to be able to make a more extensive contribution to Rapid Switch and the work of the Dow Centre in 2018. Stephen teaches his students that in energy markets physics, prices and policies all need to be considered together: principles he brings to his research and contribution to the Dow Centre.

Dr Bronwyn Laycock, Senior Lecturer

Dr Bronwyn Laycock is a polymer scientist with an interest in advanced materials for sustainability. She is currently working across a range of projects, including novel biopolymers and their composites, particularly waste derived, and the applications of these in controlled release formulations (for fertilisers, agricultural chemicals, and veterinary applications). She also has projects in self-assembled conducting peptides, spinifex to carbon fibre conversion, hydrogels for nutrient management, lignin-based polyurethane foams and waste to diesel conversion. Within the Dow Centre she is delivering the Next Generation Fertiliser program as well as leading the Food Waste Transformation program in the Fight Food Waste and Fraud CRC bid, which she is supporting with an ARC DP grant application in food waste accounting, along with Joe Lane and Paul Lant.

Highlights for 2017 included winning almost $6 million in grant funding, the publication of 10 papers and two book chapters, and a major CRC submission on Fighting Food Waste and Fraud, which went to final interview with promising feedback in February 2018. Within this bid Bronwyn is the Program Manager of the Waste Transformation program.

Future goals are to continue to deliver innovation in areas that will make a step change contribution, such as in cost-effective nutrient management, food waste management and recovery, and delivering solutions for plastic use in the circular economy.

There are many global challenges that need to be addressed, most of them wicked problems. However, in many cases there is room for true innovation that has the potential to deliver real improvement in global outcomes. The Dow Centre is well-positioned to deliver such innovation.

Dr Simon Smart, Senior Lecturer

Simon Smart 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 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.

The main objective of his 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 greenhouse gas emissions. To this end his research program has two main themes, the first of which forms the focus of his work at the Dow Centre: *Developing materials, processes and enabling technologies for sustainable energy, chemicals and water production*, and *The role of energy in society, particularly around the rate of global decarbonisation and the impacts on climate and the economy as well as the links between energy access, affordability and poverty*.

Simon is currently leading the Dow Centre's flagship projects into low CO_2 production of materials and chemicals and contributes to the Rapid Switch initiative. The low CO_2 production of hydrogen, iron, syngas and cement is an essential part of decarbonising heavy industry. These project focus on utilising molten metals and salts with natural gas to facilitate innovative processes which may prove major technology disruptors for their respective industries. Rapid Switch seeks to answer the question of how fast we can decarbonise the global economy and is unique in all the climate and energy literature for taking an engineering-based infrastructure delivery approach.

2017 highlights include a three month research visit with collaborators at University of California, Santa Barbara and the development (and launch in January 2018) of a new MOOC for energy on the UQx platform – ENGY0x – Energy Principles and Renewable Energy

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.

Professor Eric McFarland, Senior Consultant

From January 2014 till December 2015 Professor Eric McFarland was the Dow Centre's inaugural director. During this period he was particularly interested in carbon-free production of energy and chemicals using nuclear processes, carbon dioxide reduction technologies and cost-effective, low-carbon dioxide, catalytic processes for methane conversion. January 2016 he returned full time to the University of California, Santa Barbara but he retained collaborative projects with UQ and the Dow Centre.

Eric studied nuclear engineering at U.C. Berkeley and the Massachusetts Institute of Technology (MIT) where he received his PhD and later joined the Nuclear Engineering Department. He moved to the University of California, Santa Barbara (UCSB) where his research focus shifted to chemical reaction phenomena and catalysis. Prior to his move to The University of Queensland in 2014, he was a Professor of Chemical Engineering at UCSB. Eric has worked extensively with industry and started and led several technology companies based on university research, among them Symyx Technologies and Gas Reaction Technologies. Eric also studied medicine and received his M.D. from Harvard Medical School and practiced emergency medicine part-time 2005; he has continued to serve as a volunteer physician for several relief agencies.

Dr Joe Lane, Research Fellow

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

Dr Luigi Vandi, Research Fellow

Luigi Vandi is a Research Fellow with a diverse background in Materials Science, ranging from manufacturing, in-life performance and end-of life conversion to higher value products. His translational research activities have a strong focus on industry relevant projects. This included high-performance composites manufacturing for automotive and aerospace applications, while working at Ferrari F1 Team in Italy. In Australia, he also played a key role in developing a patented technology as part of a collaborative project with Airbus. He further gained expertise in biocomposites and biopolymers during the development of novel sustainable materials based on wood and marine-degradable biopolymer, in close collaboration with Norske Skog Paper Mills. In his role at the Dow Centre, Luigi is focusing on the materials development for the next generation fertilizers. Successful outcomes would address a global issue with nitrogen and phosphorous losses in agriculture. Being part of a multidisciplinary team with a worldwide vision on sustainability, energy and waste management is something which he finds very valuable and stimulating. Luigi is driven by solution-based research, and in particular bringing latest innovations in materials science to the benefits of a future circular economy. His future goals are to grow an expertise at the nexus between materials science, sustainable development and bioprocessing, and to significantly contribute to changing today's linear economy.

Dr Khuong Vuong, Research Fellow

Khuong is currently focusing on the laboratory component of the 'Low CO_2 Iron Production' project. He is interested in this project because of the significant challenges it presents, as well as the big impact it could provide, if successfully implemented. He hopes to work collaboratively with industrial partners to expedite the project in the future. In addition, he is also the laboratory manager for the Dow Centre's research laboratory. With colleagues, Khuong has made and continues to make important improvements to the laboratory. Khuong completed his PhD at the University of New South Wales, Australia in the area of organometallic chemistry and catalysis. Since then he has worked as a researcher at several universities and research institutes in Australia and overseas. He participated in a number of successful collaborative projects and has good experience in synthetic chemistry, catalysis, photo-chemistry and biomass conversion. Khuong is interested in developing environmentally and economically sustainable chemical processes.

Dr Martin Stringer, Research Fellow

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

Dr Benjamin Ballinger, Postdoc. Research Fellow

Ben's primary research focused on the Rapid Switch project. His research interests centred 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 was on the separation of contaminants from both gaseous and liquid waste streams. In August 2017 Benjamin left the Dow Centre and moved to Malaysia.

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. In August 2017 Diego was appointed at the Gold Coast City Council where he now manages the delivery of energy generation projects and the implementation of energy efficiency retrofits. He is also teaching in UQ's 'Masters of Energy' program.

Dr Taiwo Odedairo, Postdoctoral Research Fellow

Taiwo joined the Dow Centre team as a Postdoctoral Research Fellow in 2017. He currently works on the dry reforming of methane and low-CO_2 iron production projects. He received his Bachelor and Master of Science in Chemical Engineering from Obafemi Awolowo University (OAU), Ile-Ife, Nigeria and King Fahd University of Petroleum and Minerals (KFUPM) in Saudi Arabia, in the years of 2006 and 2010 respectively. He was awarded his PhD in Chemical Engineering from the University of Queensland (UQ), Australia in 2016. Prior to his PhD program, he worked for two years with the Saudi Arabia Basic Industries Corporation (SABIC), a leading petrochemical company. He has acquired skills in the areas of industrial processes and operations including process optimization, engineering design and management, design of experimental procedures and conditions, review and updating of standard operating procedures and administration. His main research areas are in functional materials, nanotechnology, clean energy, fuel cells and H_2 production.

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 worked in the areas of organic chemistry and sustainable energy technology. Xiaoyu moved to New Zealand where she is now working for Fonterra Co-operative Group Ltd.

Ms Mojgan Tabatabaei, Analyst

Mojgan received her BE degree in chemical engineering and was awarded top student rank from Iran University of Science and Technology in 1993. As a graduate engineer, she joined the Air Quality Control Company in the position of environment engineer focusing on air pollution, establishing air monitoring facilities in Tehran with collaboration of international organization such as World Bank and World Health Organization. She then went on to earn her ME degree in chemical engineering from Tehran University, Iran in 1997 and joined to the Islamic Azad University as an academic staff. Mojgan joined the Dow Centre in 2014 as a techno-economic analyst.

Mr Brett Parkinson, Analyst

Brett is a chemical engineer (BE/ME 2014, Hons) who worked as a consultant research officer and technical analyst at the Dow Centre from late 2015 to mid-2017. His work initially spread across a range of topics including process modelling of radiation chemistry, reactive distillation and halogen chemistry. His later work focused on the Low-CO_2 production of iron and petrochemicals via various synthesis routes. Brett has since left the Dow Centre to undertake his PhD at Imperial College London, funded by a General Sir John Monash Woodside Scholarship. His PhD focuses on methane pyrolysis in molten salt and metal-salt systems for the low-CO_2 utilisation of natural gas for petrochemicals and fuels.

Mr Ben Kefford, Research Assistant

Ben graduated from The University of Queensland in 2016 with a Bachelors and Masters in Engineering (Mechanical & Aerospace), where he was distinguished as a UQ Future Leader for his extensive work in research, both domestically and internationally. Following graduation, Ben joined the Dow Centre as a Research Assistant, forming part of the core team working on the Rapid Switch project. Ben's work focussed on analysing the impacts of deep decarbonisation scenarios such as the 2-degree scenario outlined by the IEA, providing a footing for the Rapid Switch proposal that was presented to stakeholders around the world. Ben left the Dow Centre in early February 2018, taking a job as an analyst at KPMG in Brisbane. Working in the Infrastructure & Projects team, Ben uses his experiences from the Dow Centre to help develop proposals for renewable energy projects around Australia, incorporating financial and energy system modelling.

Dr Rijia Lin, Research Assistant

Rijia obtained his Bachelor of Engineering and Master of Science from Sun Yat-sen University (China) in 2010 and 2012 respectively. He was awarded his PhD in Chemical Engineering from the University of Queensland in 2016. During his Master, he was working on the project of functionalization of polymers for CO_2 adsorption. During his PhD, his research focused on the development of novel porous materials and fabrication of high selective mixed matrix membranes for gas separation and purification. Rijia started working at the Dow Centre as a research assistant in July 2017. He currently focuses on developing novel processes for iron production with low CO_2 emission. He is also involved in the Natural Gas Utilisation Project and works on the design of a new membrane reactor for primary methane pyrolysis.

Mr Mark Hodgson, PhD Student

Mark is a mature age PhD candidate sponsored by the Dow Centre. Previous formal education includes a Bachelor of Engineering (Chemical) and a Bachelor of Economics.
He has extensive experience in both upstream and downstream oil and gas industries, where he was able to develop and apply advanced skills in process improvement and process optimization, and the management of process safety practices. He is a Fellow of the Institution of Chemical Engineers. Mark's research explores methods to mitigate CO_2 emissions associated with production of cement. He contributes to teaching outcomes via his tutoring activities.

Ms Sara Zeinal Zadeh, PhD Student

Sara is PhD student at the Dow Centre. She obtained her Bachelor degree on Mechanical Engineering from the K.N.Toosi University of Technology in 2000. Since then she worked in the oil and gas industry as project engineer and project manager in Persian Gulf mega projects. In 2012 she moved to Australia and mid 2013 took up a one-year research project on Life Cycle Assessment of Solar Energy in Australia at the UQ Energy Initiative. After 12 challenging years dealing with fossil fuels and observing the real-in-site environmental impacts of conventional power generation technologies, she has now decided for a career change and to contribute to improving the environment. Her PhD project involves solar energy technologies, solar policy and social impacts of solar deployment. Her research is part of the wider Rapid Switch project aiming to evaluate and quantify the key constraints for the rapid deployment of solar power technologies to meet climate change targets. Sara has been enhancing her skills in techno-political and techno-social modelling within the study.

She is also involved with tutoring and mentoring of under graduate students in engineering design and project management courses. Her aim is to become an academic in the clean energy space.

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.

Mojgan Tabatabaei is a techno-economic analyst with a passion for new ideas

Mojgan received her Bachelor's degree in chemical engineering and was awarded top student rank from Iran University of Science and Technology in 1993. As a graduate engineer, she joined the Air Quality Control Company in the position of environment engineer focusing on air pollution, establishing air monitoring facilities in Tehran with collaboration of international organizations such as the World Bank and the World Health Organization. She then went on to earn her Master's degree in chemical engineering from Tehran University, Iran in 1997 and joined the Islamic Azad University as an academic staff member. Mojgan joined the Dow Centre in 2014 as a techno-economic analyst.

Mojgan's desire to work in the petrochemical industry, led to her first role as a process engineer with Nargan Engineers and Constructor Company in Iran. During this time she gained tremendous experience, rising to principal process engineer on several mega scale industrial plants which are currently in operation in Iran.

Mojgan believes that the Dow Centre provides her with new challenges and opportunities to examine the industry from a different angle. At the Dow Centre, she can apply her knowledge and experience to new opportunities to improve the technical, economic and environmental sustainability of new and novel technologies.

Combining her passion for process innovation and her economic pragmatism Mojgan is continually updating her knowledge and capability and extending her experience to a range of industries and technologies. She believes that the combination of a broad exposure to different process technologies, extensive industry experience and robust techno-economic analytical skills, positions her well to translate academic research into industrial applications.

Mojgan believes that strong links and collaborations between universities and industries are mandatory for creating real-world impact through innovative technology.

"Understanding industrial sectors' interests and barriers to acceptance can help build this connection".

The Dow Centre is playing an important role in identifying innovation opportunities and analysing barriers, helping to frame a research agenda that is most relevant to industry.

"I believe that strong links and collaborations between universities and industries are mandatory for creating real-world impact through innovative technology. "Understanding industrial sectors' interests and barriers to acceptance can help build this connection."

Research Fellow Joe Lane working to improve industrial practice

After seven years working as a process engineer in the sugar and alumina industries, Joe Lane's desire to improve industrial practice led him to commence a Master's degree in Environmental Management. Through that study, he discovered a passion for the broader challenge of integrating complex environmental trade-offs into decision making processes. This led him to redirect his studies toward building a better understanding of how economic principles shape the challenges and opportunities for taking on the most pressing (global) environmental sustainability challenges.

Joe extended and applied his skills during his five years of employment in the government water sector. His focus of that time was on integrating environmental and systems thinking into water planning processes, during a period of substantial institutional stress associated with critical regional water shortages, and a rapidly tightening social licence-to-operate for wastewater disposal systems. Motivated to extend his research skills even further, Joe then spent five years at The University of Queensland, combining a PhD with project research, continuing the focus on integrating environmental analysis into the water planning process.

During his PhD period, Joe led UQ's contribution to a ten-university collaboration, building novel software to analyse social and environmental interactions with regional economies and trade. The software greatly expanded the scope of applications, and accessibility to, such analysis. That project also provided the foundation for his ongoing research at the UQ Dow Centre, where he seeks to integrate systems analysis with more conventional techno-economic analysis. His ultimate goal is to assist policy makers and business leaders to prioritise interventions that aim to address global sustainability challenges, especially related to energy and food systems.

Transitioning our energy systems to deliver on global ambitions for meeting greenhouse gas (GHG) abatement targets represents the most substantial, and most urgent challenge, to global economies. While the trade-offs required for developed economies dominate much of the public gaze and research attention, the decarbonisation challenge in developing countries may be far more important to global GHG abatement targets. As governments in developing countries prioritise the rapid expansion of energy access to help bring populations out of poverty, it will be critical to avoid path dependencies that become bottlenecks to achieving low-GHG energy supply.

In a similar vein, the trend in global food systems is toward increasing environmental stress as a result of growing food demand, and rapidly shifting dietary preferences in the developing world. Effective policy responses to these challenges are constrained by a lack of system-level tools to analyse the extremely complex and diverse trade-offs involved. In terms of planetary scale sustainability challenges, some of these trade-offs confronting food systems are just as significant as those facing energy systems.

Overcoming these challenges will be substantially aided if technology proponents, both commercial operators and researchers, can be encouraged to apply more critical scrutiny to the system-level (big picture) implications of their proposals. At the same time, there is a need to improve the techno-economic realism (attention to detail) in modelling scenarios used to steer international policy makers when dealing with global-scale challenges.

In the research environment, such outcomes will only be realised if we move beyond the traditional focus on discipline specialisation. To improve our contribution to national and international policy making, the research community must improve its capacity to deliver systems analysis that is both more strategic in scope, more attuned to detail, and more timely. In this regard, the UQ Dow Centre, with its priority on scalable, solutions-focussed research and integrative analysis along with strong industry linkages, offers huge potential.

Joe looks forward to contributing to this endeavour, using applied research to help address the substantial environmental sustainability challenges faced by society, and to help bring about a research system that can better utilise inter-disciplinary and integrative methodologies.

> “ To improve our contribution to Australian policy making, the research community will need to improve its capacity to deliver systems analysis that is both more strategic in scope, more attuned to detail, and more timely.”

DOW Centre projects

In this section, we provide updates on the key research activities being undertaken at the Dow Centre. Our research strategy to date has been to focus on just a few projects that hold the potential to have global impact. It is a high stakes approach. Our research strategy to date has been to focus on just a few projects that hold the potential to have global impact. A broader portfolio of smaller projects would diversify risk and might maximise traditional research publication opportunities, but is less likely to generate substantial real-world impact.

To reduce risk in this high stakes approach, the Dow Centre applies a multi-disciplinary, stage gated process to its research. All technical ideas are subjected to an initial screening – early proof of concept for individual components after which comes a high-level economic analysis. This screening process allows us to filter out ideas that can be demonstrated to have little or no prospects for impact or scale, even though they might hold scientific interest. That is not to say that such research is not worthy, but that it does not fit within the Centre's strategic priorities.

Finally, we need to connect our research with industry and society. To date the flagship projects have generated considerable curiosity and interest among a range of stakeholders. The year ahead, will see an increasing focus to convert stakeholder curiosity to meaningful partnerships.

Key pursuits

TECHNOLOGY ADVANCEMENT

The Dow Centre seeks to foster the generation of new ideas and opportunities for innovation in high impact processes for sustainable production and use of energy, water, food, and materials.

ENGAGEMENT

The Dow Centre has been created as a globally relevant centre of excellence dedicated to sustainable prosperity. Our strategy is to identify and help to overcome scientific and engineering barriers, and to do this, we have built global partnerships for education and research. We seek to facilitate the development of future leaders in engineering to tackle global changes.

GOVERNMENT POLICY

The Dow Centre identifies and quantifies potential game-changing processes and outcomes. With rigorous techno-economic and sustainability analyses, we can inform government decision makers, assisting them in their policy deliberations.

ENVIRONMENTAL PROTECTION

The Dow Centre is committed to promotion, education, communication, and global cooperation that embraces evidence-based options and approaches to environmental and economic sustainability and recognise industry's key roles in enabling solutions.

Methane pyrolysis for hydrogen production

Industrial production of hydrogen without CO_2

Overview

Development of an innovative and sustainable technology to utilize methane for hydrogen production as both a chemical feedstock and a clean source of energy is a priority research area for the Dow Centre. Methane pyrolysis using molten metals and molten salts is a promising alternative pathway for hydrogen production without CO_2 emissions. Initial techno-economic analysis of an industrial scale hydrogen plant demonstrates that the molten metal technology always outperforms electrolysis and steam methane reforming with carbon capture and storage (SMR+CCS) as low CO_2 routes to hydrogen. Furthermore, it even outperforms traditional unabated SMR at a carbon price exceeding $21 per tonne CO_2. The analysis shows that the hydrogen production via methane pyrolysis is sensitive to both energy and separation costs. In order to reduce hydrogen production costs we are working on a one pot pyrolysis solution with in-situ carbon removal and hydrogen separation using the membrane reactor concept. This will reduce equipment costs, energy input and remove the need for downstream hydrogen purification. In particular, certain molten metals have good hydrogen solubility and diffusivity which allows us to design a reactor where the metal will work as both a catalyst and separation media.

Research report

The pyrolysis of methane is a direct and commercially attractive process to produce H_2 without CO_2. Downstream separation and purification of H_2 from the unreacted methane is most frequently performed using pressure-swing adsorption (PSA) with a high efficiency at low temperature. An alternative option is to use the molten metal catalyst as a membrane for high temperature H_2 separation.

Metal membranes for hydrogen separation have been extensively investigated over the last few decades with thin films of palladium-based alloys regarded as the most promising candidates. Similarly, ceramic membranes such as silica or mixed metal oxide materials have received extensive research interest. In both cases membrane reactors, wherein hydrogen is directly and selectively removed from the reactor as it is produced, have demonstrated potential to reduce downstream purification and enhance equilibrium conversion (through Le Chatelier's principle). However, these traditional membranes have suffered from stability issues and fouling due to coke production and have seen limited industrial deployment. Molten metal systems offer the opportunity to avoid coking issues altogether. However, the concept of a molten metal membrane for hydrogen separation is effectively unexplored, with only a single reported publication of a molten gallium layer sandwiched between two porous ceramic plates. It has never been applied to methane pyrolysis before.

The Dow Centre in collaboration with UCSB has launched an extensive experimental investigation to design a novel liquid metal membrane reactor. The main objective is to study the solubility and diffusivity of hydrogen in molten metal systems to facilitate both catalysis of the methane to hydrogen and removal of the hydrogen as soon as it is produced. In the schematic shown in Figure 1, natural gas is preheated, sent to the reactor vessel where pyrolysis takes place at high pressure and temperature. The hydrogen is absorbed into the molten metal and removed via porous ceramic tubes kept at lower pressure which induces the driving force for hydrogen flux.

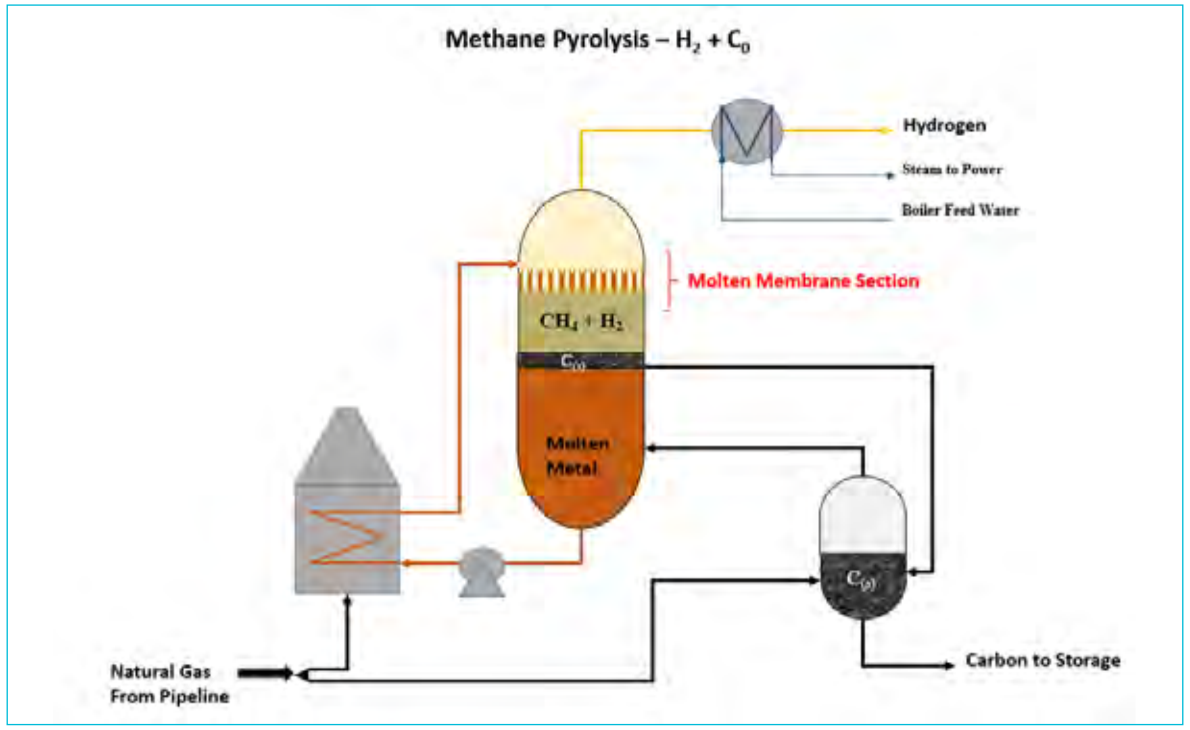


Figure 1- Methane pyrolysis in molten metals

Key people involved in project

Mojgan Tabatabaei, Brett Parkinson, Rijia Lin, Khuong Vuong, Simon Smart, Howard Fong, Eric McFarland

Key outputs

B. Parkinson, M. Tabatabei, D. C. Upham, B. Ballinger, C. Greig, S. Smart, E. McFarland, Hydrogen Production using methane: Technoeconomics of decarbonising fuels and chemicals, International Journal of Hydrogen Energy, 43 (2018) 2540-2555

Low CO_2 production of iron

Using new chemistry to explore lower cost decarbonisation pathways

Overview

Iron and steel production is the largest energy consuming industry in the world and one of the largest CO_2 emitting industries producing around 5% of the world's greenhouse gas emissions. The main focus of decarbonisation scenarios for the iron and steel sector is carbon capture and storage (CCS) at an estimated cost of between $70 and $120 per tonne of CO_2, assuming suitable geological resources to store CO_2 are available. Three of the top four steel producing countries (China, Japan and India) may have limited suitable geology, bringing CO_2 reduction strategies into question. Direct reduction with hydrogen or electrolysis technologies for iron production with a high share of renewable energy are not economically attractive without a very high CO_2 price.

This project seeks to use new chemistry to explore lower cost decarbonisation pathways. The original approach was a unique process to co-produce iron and organic chemicals utilizing natural gas without direct CO_2 emission through a chemical looping concept. In this scheme, reduction of iron ore and natural gas conversion were facilitated by a molten salt mixture and electrolysis. Due to process complexity, that process has been shelved in favour of a simpler scheme that focuses on iron production, with a solid carbon by-product.

Research report

The new process for the low CO_2 production of iron is shown schematically in Figure 1. Here, iron ore is first converted to iron chlorides using hydrogen chloride and then the molten salt mixture is reduced to solid iron by using methane, methyl chloride and hydrogen in a bubble column reactor. Iron and solid carbon are formed and separated from a molten salt mixture as main products. Hydrogen chloride is also formed as a by-product which is then recycled to an ore chlorination reactor along with any unreacted methane. The morphology, and therefore value, of the solid carbon product is currently unknown. However, we have strong evidence from our methane pyrolysis work that the carbon morphology can be controlled to produce carbon by-products of potential value.

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

Extensive laboratory investigations are ongoing at the Dow Centre. The results for both the iron production and ore chlorination are encouraging. For the iron production section:

- Iron(0) was produced using either methane or hydrogen as the feedstock.
- Enhanced methane conversion and HCl production i.e. iron(0) production, with the addition of suitable additives.
- Various salt eutectics have been investigated in order to improve the reaction.
- Confirmation that increasing temperature can significantly increase the conversion of methane and in turn iron(0) production.

The initial work on the ore chlorination section showed positive results for the co-reduction of Fe_3O_4 with HCl and H_2, producing high yields of $FeCl_2$ as a stable intermediary which is suitable for the high temperature reduction to iron with methane. However, there are significant challenges in obtaining reaction kinetics for the direct production of Fe(0) *in situ* in real time. Therefore a further investigation is underway to develop an electrochemical method for quantification of iron species in the salt mixture at high temperatures.

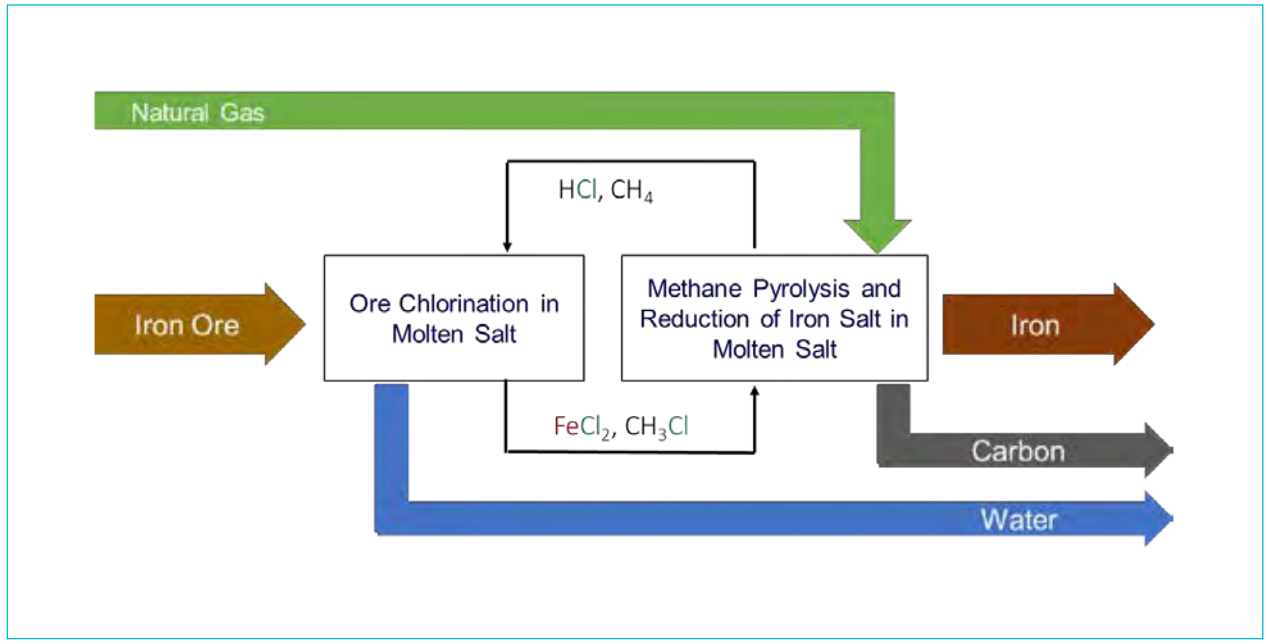


Figure 1 - A simplified block flow diagram of the low CO_2 production of iron

Using a eutectic molten salt mixture as a facilitator for iron ore reaction led us to a further innovative idea for a direct reduction of iron ore with methane to produce syngas as a by-product. This new approach provides another opportunity for co-production of iron and chemicals by simplifying the process and eliminating the halogen-based chemical looping. Experimental investigation has commenced in the direct reduction of iron ore in molten salts with encouraging preliminary results.

Key people involved in project

Simon Smart, Chris Greig, Eric McFarland, Khuong Vuong, Brett Parkinson, Mojgan Tabatabaei, Taiwo Odedairo, Rijia Lin

Dry reforming of natural gas in molten metal and salt systems

Industrial production of hydrogen without CO_2

Overview

This project departs from the typical Dow Centre perspective on CO_2 emissions – using innovative chemistry and process routes to avoid the production of CO_2 in the first place – and instead focusses on how to use innovative chemistry to utilise CO_2 with natural gas to produce syngas. Dry reforming (DR) has long been investigated as a viable pathway for the conversion of methane to chemicals with the added benefit of CO_2 utilization. However, traditional dry reforming technologies have been plagued by catalyst sintering, instability and coking. Likewise, alternative production through utilising plasmas or electrochemistry is yet to demonstrate economic viability, much less comparable economics to other forms of methane utilisation.

The Dow Centre is using catalytic molten metal and molten salt systems to improve current DR technologies, enhancing overall efficiency and avoiding catalyst deactivation. In particular the molten state of the system means that coke production is no longer a problem as any carbon produced simply floats on top of the melt and can be removed. Indeed, carbon production can be encouraged, through feeding excess methane into the reactor, as it is accompanied by increased hydrogen production. This enables DR to produce high value syngas with H_2/CO ratios in excess of 2 and has the potential to unlock natural gas fields with high CO_2 content, or as an option to utilise CO_2 instead of geological storage.

Research report

Syngas (CO and H_2) production via dry reforming of methane on solid heterogeneous catalysts was identified as a suitable strategy to mitigate CO_2 emissions, but has long faced issues of catalyst coking and deactivation. Using molten metal catalysts avoids these problems entirely as the carbon simply floats on the melt surface as with methane pyrolysis. Further, integrating conventional heterogeneous catalysts with a molten salt system has been identified as a promising approach to prevent the catalyst deactivation with further enhancement of the catalytic activity. Molten salt systems have the potential to remove carbon as it is produced and thereby keep the solid catalysts coke free. Both process options are investigated by the Dow Centre as part of this project.

Figure 1 shows a simplified process scheme for application of the proposed process in a natural gas field. The raw natural gas from the reservoir is preheated and routed to the molten reactor after desulfurization of natural gas. The dry reforming reaction between methane and CO_2 occurs in a molten media in the presence of a suitable catalyst. The produced syngas is sent to the downstream unit for further processing and excess carbon is floated to the surface of the molten media in the reactor to be skimmed off and sent to a downstream unit for further separation. The novel system shows the possibility of producing a higher H_2/CO ratio in comparison with the current DR technologies which can directly be used for the production of value-added chemicals/fuels with continuous carbon removal. In theory any syngas ratio >1 can be produced simply by feeding excess methane. The extra hydrogen production will be accompanied by an increase in solid carbon by-product and enable complete utilisation of the CO_2.

Extensive investigation and experiments of the integrated system are ongoing at the Dow Centre in strong collaboration with UCSB. We have designed and developed a lab-scale reactor, tested different molten media and are currently optimizing the integrated system. The initial experimental results show promising catalyst stability compared to the conventional system. The test is currently being extended to other cheap catalysts with higher catalytic activity. The next stage of this project will develop a variety of process configurations which will undergo full technoeconomic analysis to identify the cost effective factors and key economic parameters of this novel process.

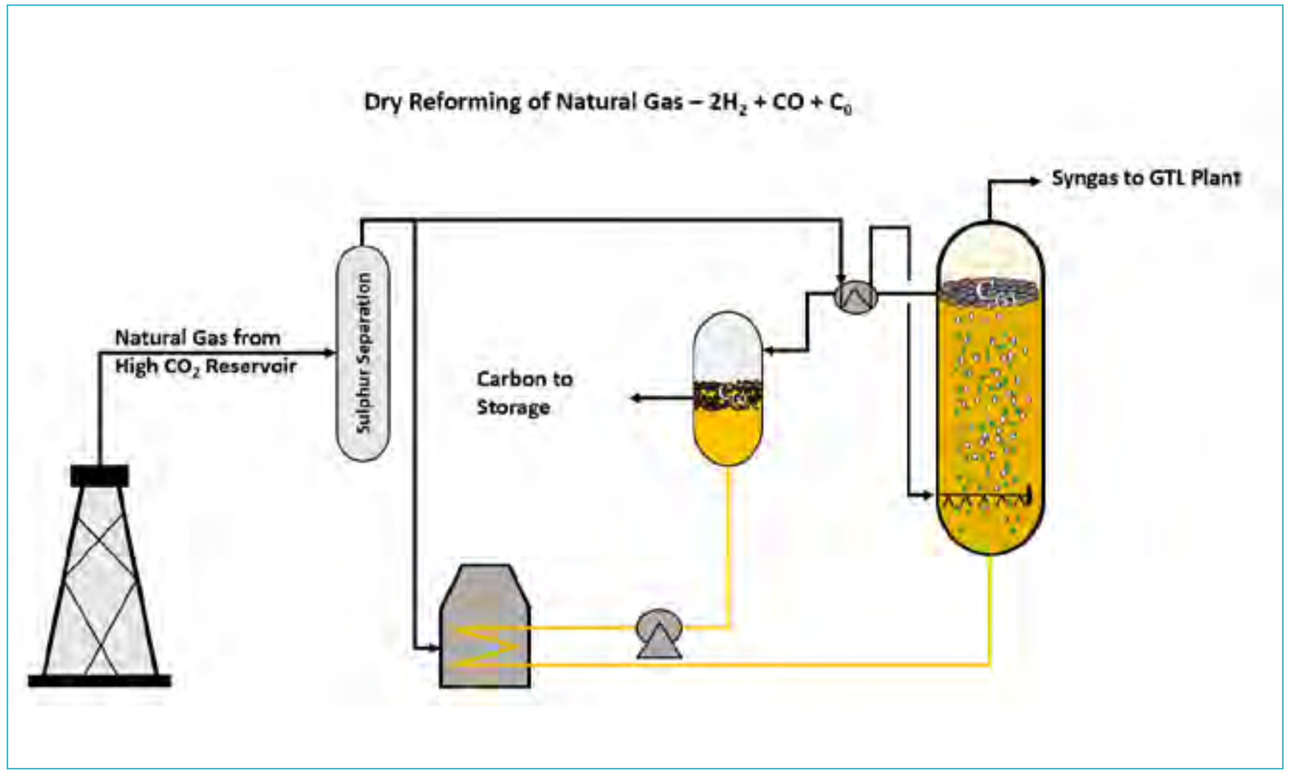


Figure 1- Simplified process flow diagram for dry reforming of natural gas in a molten system

Key people involved in project

Taiwo Odedairo, Mojgan Tabatabaei, Simon Smart, Chris Greig, Howard Fong, Eric McFarland

Key outputs

Manuscript on dry reforming in a molten nickel indium system to be submitted to Energy and Environmental Science or Nature Energy in first quarter of 2018.

Manuscript on dry reforming using traditional heterogeneous catalyst in molten salt systems to be submitted to Energy and Environmental Science or Nature Energy in the first quarter of 2018.

The Rapid Switch Project

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

Overview

As the world confronts three key socioeconomic megatrends – population growth, GDP growth and climate change – we face a sustained period of massive change to energy systems, industrial production and the economy more generally. Navigating these changes will require unprecedented innovation, planning and investment along with social change. We need a better understanding of these transitions and new models if we are to achieve our ambitions for economic development and climate change mitigation.

Climate models illustrated below are used to describe the link between increases in atmospheric greenhouse concentrations and impacts on climate change (e.g. the rise in global average temperatures).

Another group of models, broadly termed integrated assessment models, describe potential sectoral and technological transitions that would deliver targeted reductions in greenhouse gas emissions over time. Figure 2 provides two such examples from the International Energy Agency's 2017 Energy Technologies Perspectives.

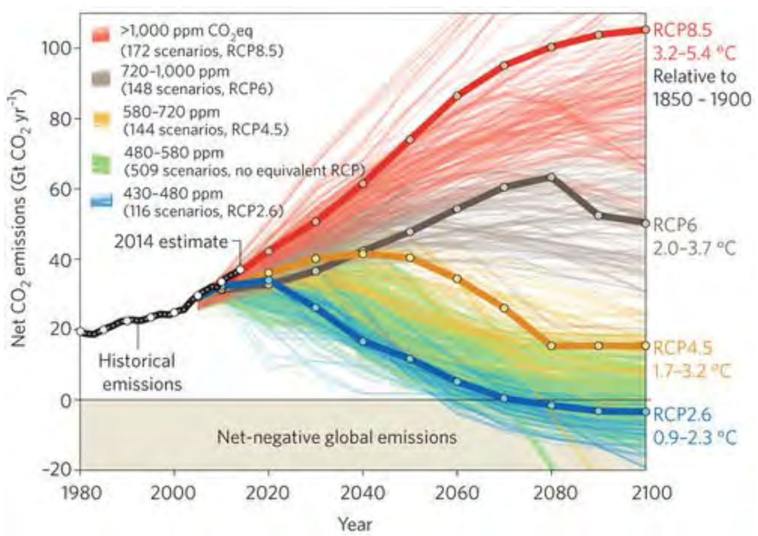


Figure 1- Climate models project warming that is likely to result from different GHG emissions trajectories.

The critical question that is not well-addressed in the literature and which provides the motivation behind Rapid Switch is - ***How rapidly can the world's energy system be decarbonized?***

Over the past year, the Dow Centre has analysed various technology transitions in different sectors and regions providing considerable evidence that many of the transition scenarios are likely to face a range of technical, economic, infrastructural, regulatory and social, behavioural and cultural issues that may constrain a rapid energy system transformation.

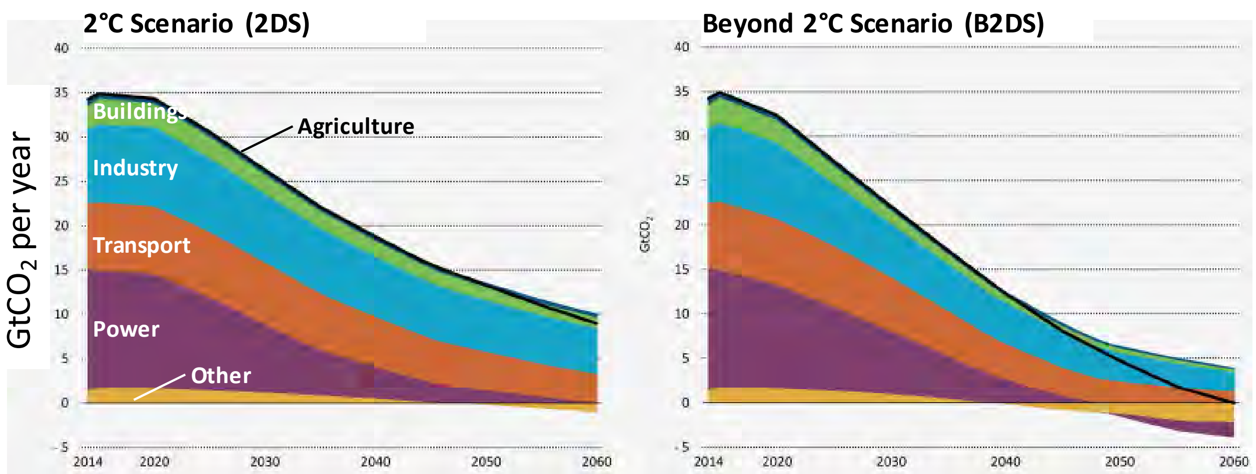


Figure 2. Illustrative global energy-related CO_2 emissions trajectories for limiting global warming to 2°C (left graph) or 1.75°C (right graph) above the pre-industrial level.

Our ability to understand, anticipate and overcome bottlenecks, at regional and sub-regional levels, is critical for maximising the pace of change and minimizing risks and costs of transitioning globally to low-carbon economies. Given the current trajectory of global emissions, insights into what bottlenecks could slow the pace of decarbonisation, communicated effectively should provide better informed public policy and private investment decision-making.

The Rapid Switch project is enormously complex and requires a diverse range of capabilities and perspectives. To this end we are collaborating with a number of international partner universities including Princeton, Carnegie Melon, Tsinghua University and IIT Mumbai as well as other research institutes. Our plan is to continue to add partners from other regions such as Europe, ASEAN and ultimately Africa and South America.

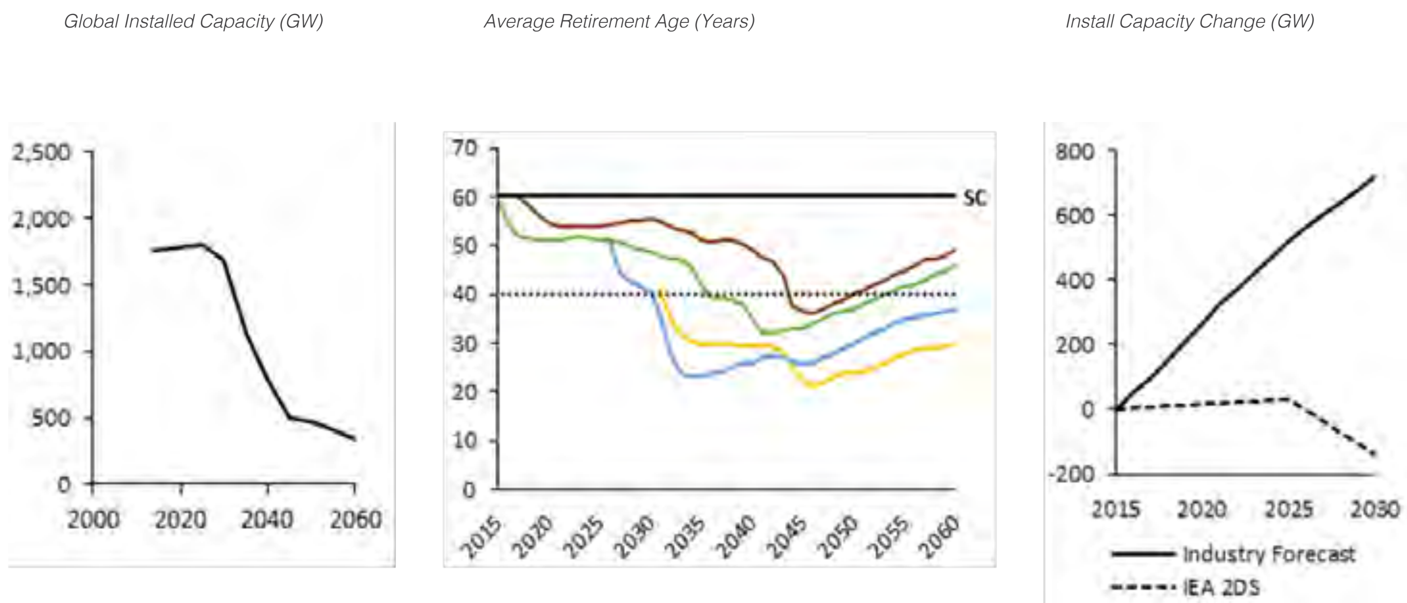
Research report

Progress in 2017 focussed on three objectives:

1. Framing the research agenda for the project by identifying bottlenecks which have the potential to materially impact on the pace of the global low carbon transition.
2. Demonstrating how to develop, analyse, and address the key research questions that will help us deliver new useful insights to policy makers and industry.
3. Identifying priority research areas based on regions, sectors and/or technologies which face a greater likelihood of bottlenecks and with the greatest consequences that those bottlenecks might have on climate mitigation.

Framing the Research Agenda - The team identified a range of potentially significant bottlenecks.

Early retirement of legacy carbon-intensive assets. The work focussed on the electricity sector and showed that deep decarbonisation scenarios require both a stop to new coal fired generation investment and for the majority of coal assets globally to be retired from service before mid-century. As the figure below illustrates, this means many planned and under construction projects must be halted and many plants both existing and under construction must be retired much earlier than historically has been the case for such assets.



- A range of supply chain and human capability bottlenecks will potentially emerge where rates of change are the greatest. Examples of material supply chains facing extreme growth rates relative to current production capacity include polysilicon, high density float glass manufacture, coproduced rare earths such as tellurium all used for solar PV and monoethanolamine used for CO_2 adsorption in CCS. Examples of rapid transformation of labour markets include increases in labour for India's solar industry and rapid reductions in employment facing the coal sector globally.

Methods - A key new method was utilised to understand the potential impact of various regulatory, environmental and social bottlenecks based on Bayesian Belief Networks (BBN). A preliminary model was developed for CCS as a proof of concept. The work involved expert elicitation to provide perspectives on the key bottlenecks in different regions of the world and using these to populate the BBN. The output is a probability distribution of the likely deployment as a percentage of the maximum potential in a given region. A journal paper is being prepared for submission.

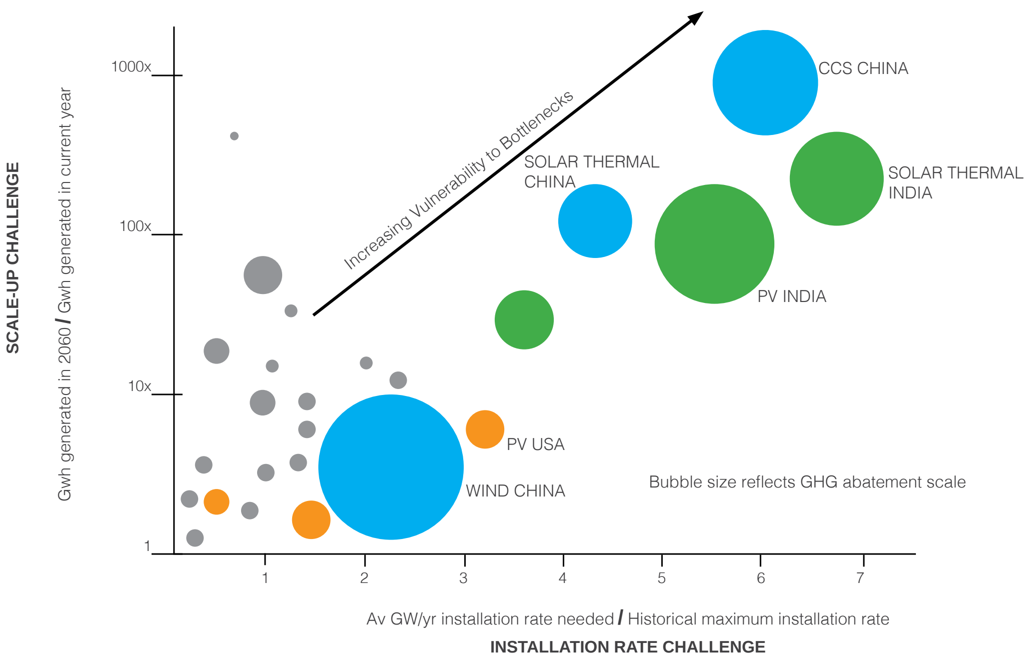
The Dow Centre also secured a licence for BAEGEM, a general equilibrium model developed here in Australia by BA Economics with its origins in the Australian Bureau of Statistics. The BAEGEM model was assessed to offer the most granular disaggregation of the economy by region, industry and energy technology and will allow us to develop our own energy transition scenarios and to explore the impacts of industrial and social bottlenecks on the viability of those scenarios.

Identifying priority focal areas - Understanding the sectors and technologies most exposed to bottlenecks which have the greatest consequences for global CO_2 reductions, on a regional basis, helps us prioritise the focus of Rapid Switch.

The following approach developed by Dow Centre Fellow Joe Lane helps rank the various technologies by region. The y axis shows the relative increase in scale of a particular transition to 2060, while the x axis indicates the pace of development relative to any historical precedent for that technology. The greatest exposure to potential bottlenecks is found in the top right hand quadrant.

This approach suggests that solar in India, CCS in China, and energy intensity reductions in both India and China present the most significant risks and uncertainties to climate mitigation.

These will be a major focus in 2018.



Key people involved in project

UQ: Chris Greig, Simon Smart, Joe Lane, Stephen Wilson, Ben Kefford, Martin Stringer, Mark Hodgson, Sara Zeinal Zadeh, Ben Ballinger.

External: Eric Larson (Princeton), Robert Socolow (Princeton), Elke Weber(Princeton), Mitchell Small (Carnegie Melon), Gabrielle Wong Parodi (Carnegie Melon)

Conceptual design of waste to energy plant- thermal plasma gasification technology

Project description

The Dow Centre developed a conceptual model and a first-order techno-economic assessment for Neocology Pty Ltd. Their process involved a novel plasma gasification technology to convert waste to energy. A process simulation model using Aspen-Plus was developed for three different client-specified scenarios. Significant cost and technology performance uncertainty were identified with the design of the thermal plasma gasification reactor due to a lack of information on feedstock compositions and the absence of any experimental data especially in relation to reaction kinetics.

A techno-economic analysis was undertaken to evaluate the financial viability of each scenario. The team developed scoping-level estimates of capital and operating costs along with revenue projections under a range of scenarios. A discounted cash-flow model was then developed to evaluation the financial viability under each scenario. The analysis suggested that financial viability would be challenged without significant technology cost reductions and scale-up.

Key people involved in project

Mojgan Tabatabaei, Chris Greig

Techno-economic modelling for a novel electrochemical separation process

Project description

The Dow Centre will develop a generic process model for a continuous, multi-stage, electrochemical isotope separation process and provide a techno-economic assessment for Ubaryon Pty Ltd. The model will rely on experimental data from a laboratory-scale batch system. A block flow diagram and process model, estimated capital costs of major equipment and operating cost, will be the principal inputs for a conceptual-level techno-economic analysis. A sensitivity analysis result will help to identify the cost-sensitive elements of process and the key economic drivers for this innovative process.

Key people involved in project

Mojgan Tabatabaei, Simon Smart, Chris Greig, Eric McFarland

Techno-economic analysis of EFI technology – convert wood waste into diesel

Project description

UQ Chemical Engineering and Eco Fuel Innovations (EFI) recently commenced a project to develop EFI's technology to convert a variety of wastes into transport quality diesel. The expectation is that the EFI technology could provide an opportunity to generate value from wastes that are otherwise difficult to dispose of. The Dow Centre was commissioned to critique the techno-economic and environmental performance of the technology, so as to help the partners identify priority areas for their research program.

The Dow Centre analysis focussed on one potential application for the EFI technology, using contaminated wood waste as a feedstock to produce 3000 litres per hour of product diesel. For this, we built a first-order process model in ASPEN-plus, based primarily on the design for EFI's existing pilot plant operations, and the preliminary pilot-plant data available to date. This process model formed the basis for the techno-economic analysis, using first order capital cost estimates with a Lang Factor methodology, and discounted cash flow analysis to test the sensitivity of the process to different assumptions for energy and materials costs, feedstock credits, and plant lifetime. The environmental life-cycle assessment considers the net greenhouse gas and energy implications for this particular waste recovery system, expanding the scope to also consider the implications of utilising alternative waste feedstocks.

Key people involved in project

Mojgan Tabatabaei, Joe Lane, Chris Greig

Testing of HCl generation reaction and brine electrolysis cell

Project description

The Dow Centre performed experiments for Australian Biorefining Pty Ltd (ABR) and Procom Consultants (Procom) and Procom to evaluate technical questions related to HCl generation and their brine electrolysis cell. After the completion of the initial HCl generation phase, the Dow Centre accepted a proposal by ABR to extend the work to the testing of the brine electrolysis cell. This consultancy project was successfully completed within a three months' period and the technical questions were satisfactorily addressed. The final report, with our technical recommendations, was submitted to ABR and Procom in August 2017.

Key people involved in project

Dow Centre: Brett Parkinson, Khuong Vuong, Simon Smart

ABR-Procom: Graeme Linklater (ABR), Tim Lloyd-Smith (Procom)

Next generation fertilisers

Background

Modern agriculture relies on mineral fertilisers to replace the main essential nutrients (N, P, K) removed with the harvest product. However, conventional mineral fertilisers, being water-soluble salts, have inherent inefficiencies, with around 50% of the applied nitrogen being lost to the environment. The problem is evident in agricultural settings throughout the world. It has significant impacts on land degradation and ocean health, including in Australia for the Great Barrier Reef. This project attempts to improve the efficiency of fertiliser use and reduce the environmental consequences using material science, applications design and microbiology.

The overall approach is to:

1. Sorb nutrients onto silica (clay, other) matrices – enabling bioavailable nitrogen release
2. Use tailored starch binders for environmentally responsive release
3. Coat with natural humics isolated from waste to enable roots to interact with fertiliser particles
4. Include pH triggers from acidic root environment (double layered hydroxides)

The project is a collaboration between the Dow Centre, the School of Chemical Engineering, the School of Agriculture and Food Sciences, the Queensland Department of Agriculture and Fisheries (DAF), James Cook University and the Manildra Group.

Highlights of 2017

This project was awarded an Advance Queensland Innovation Partnership (AQIP) grant of $680K in cash over three years. In addition, funding support from an RR&D4P grant led by DAF, Sugar Research Association and Cotton RDC of $96K was already in place. The agreement was signed in December and the recruitment of a postdoctoral materials scientist took place early 2018.

Detailed Matlab-based models have already been developed for the controlled release of active agents from a range of material types and morphologies, using this baseline work to identify optimum processes and materials for matching product requirements (both encapsulation of soil active agents and controlled release of fertiliser).

The manufacture of the initial round of encapsulated materials has been completed and water and soil-based studies to support the model development have been undertaken.

Preliminary work on the advanced composite materials has commenced, with support funding from the Dow Centre for Dr Luigi Vandi for 6 months, with initial water and soil-based elution studies informing the next stage of pot trials and next generation formulation development.

Further comprehensive studies on nutrient release and plant growth and development using previously developed formulations have been conducted, with initial results now being assessed.

Activities planned for the next year

- Complete screening studies for current round of materials (soil based elution in particular)
- Complete literature review on the structure/property relationships for inorganic additives
- Prepare further formulations, including the use of commercial (model) humics, plus extend controlled release formulations for the DAF project (through PhD student Ian Levett)
- Undertake pot trials as further screening (visualizing impact on roots as well as looking at microdialysis for nitrogen migration studies) – and prepare for field trial studies in 2019

Key people involved in project

Bronwyn Laycock, Steven Pratt, Susanne Schmidt, Damien Batstone, Paul Luckman, Luigi Vandi, Ian Levett (PhD student)

Cost effective insulation foams for emerging economies

Background

The Dow Centre director agreed to provide seed funding to support exploratory scoping studies aimed at identifying opportunities for large scale production of low-cost insulation foams in emerging economies. A Postdoctoral Fellow (Luigi Vandi) was appointed part-time for 3 months to undertake a preliminary review of the potential materials development opportunities. The submitted review addressed the following:

- Overall foam markets and costs.
- The typical insulation requirements for developed countries.
- Comprehensive tables including materials, costs and processes.

Included in this report were:

- Requirements for emerging economies and the different categories of need.
- Opportunities for novel low-cost insulation foams.
- General scale of the opportunity

The findings from this report suggest that the development of novel low-cost insulation materials can be approached by developing a next-generation sustainable polymer with similar insulation performance to medium range products (polyurethanes, polystyrene, phenolic), or through the use of a waste stream material with similar performance to fibreglass, mineral wool and cellulose. Neither of these options were yet found to be available as commercial products in the current market. Work is currently underway (with Prof. Darren Martin) to develop alternative lignin-based PU foams, with commercially relevant properties already achieved at a lower cost. Preliminary results indicate that good performance can also be achieved using biopolymer foams, although the cost differential may make this approach prohibitive unless cost effective polymers such as polylactic acid are used. To date no work has been conducted on the waste stream foams and they are unlikely to be economic to collect and use, particularly in developing countries.

The foams review has now been submitted as a publication and is under review. An initial publication on lignin based PU foams has also been prepared and is under review.

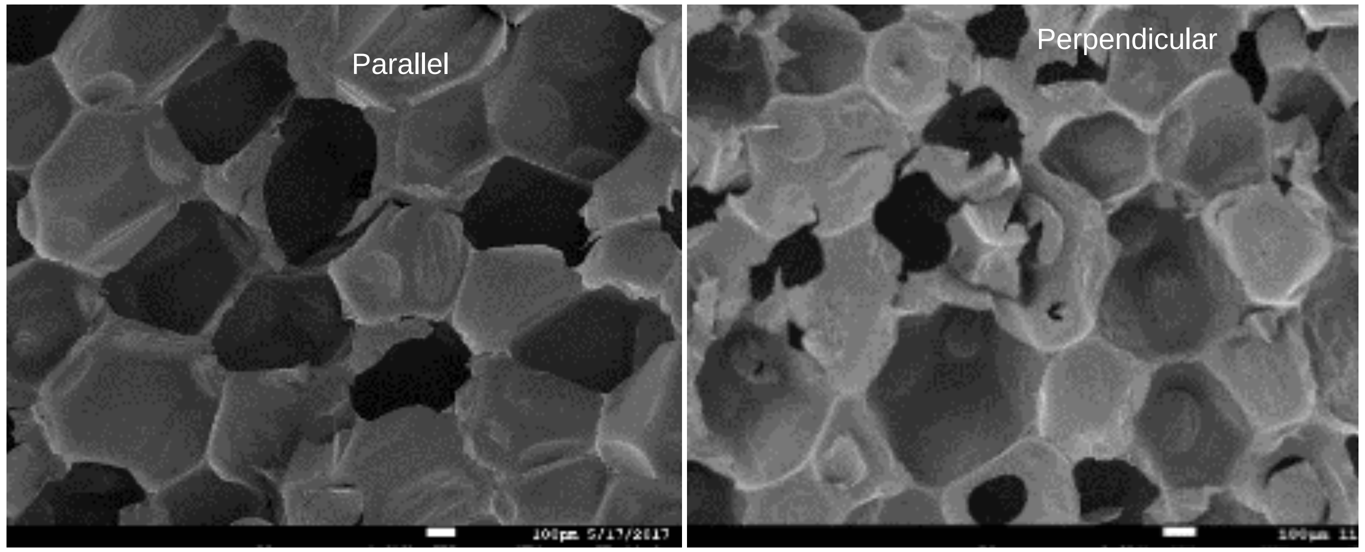
Activities planned for the next year

Research will continue with Darren Martin and David Evans (CEO Tenasitech) on lignin based polyurethane foams. There will be no other activity within the Dow Centre on low cost insulation for emerging countries.

Key people involved in project

Bronwyn Laycock, Luigi Vandi, Chris Greig

SEM images of cross-sections in parallel (left) and perpendicular (right) to the foam rise for rigid polyurethane foams containing lignin



Decarbonising cement production

Background

The global cement industry presently accounts for around 7% of overall GHG emissions. Cement production is at around 4.2 billion tpa. This is a 25% increase over predictions made a decade ago, and can be attributed to elevated cement production in China. The World Bank predicts on-going population growth and increasing urbanisation, leading to continuing strong demand for cement.

The IEA 2DS involves the capture and sequestration of 740 million tpa of CO_2 by 2060. A more aggressive scenario targets 1800 million tpa. CCS adds around 100% - 150% to the supply cost of cement. The first pilot test of cement industry CO_2 CCS is scheduled for 2020 (subject to funding approval), which lags International Energy Agency expectations.

Research opportunity

This research will examine process options designed to avoid a significant portion of CO_2 emissions. For example, reforming of natural gas over limestone leads to the coproduction of syngas and the calcium oxide suitable for cement production. Attention will also be directed to process adjustments leading to improved thermal efficiency, and reduced fuel consumption. The reference point for process energy consumption and economics is that which would otherwise be devoted to CCS.

Key people involved in project

Mark Hodgson, Simon Smart, Chris Greig.

In 2017 Dow Centre staff members were involved in two separate Cooperative Research Centre (CRC) applications. Both bids were selected for the final round and results are due to be announced in March 2018.

Although it is unsure whether either of the bids will be successful or not, the insights and experience gained during the planning and writing phase will be useful in future applications in the respective research areas.

Fight Food Waste and Fraud CRC Bid

Background

The Fight Food Waste and Fraud Cooperative Research Centre (CRC) aims to tackle the growing international problem of food waste and fraud by developing the circular food economy in Australia to transform 'waste' into value-added product, and by protecting the integrity and provenance of our food and wine products, both domestically and abroad. The total value of the bid is $169.8 million over 10 years (cash and in-kind), with a cash request to the CRC of $41.75M and total cash commitments of $44.757M. Participants include 10 research and 65 Industry partners.

This CRC is structured around four programs of activity:

Program 1: Transforming Waste Resources, which seeks to transform unavoidable waste into innovative co-products

Program 2: Reducing Supply Chain Losses, which involves mapping of resource and waste flows, improved cold chain management, extending shelf life through advanced packaging.

Program 3: Protecting Provenance and Brand, which seeks to provide solutions for managing the deliberate substitution, addition, tampering or misrepresentation of food, which is estimated to cost Australian food exports in excess of $1.7B annually. This program will develop cost-effective, rapid and robust tools and systems that can be used to verify the quality and origin of Australian foods and beverages.

Underpinning these activities is a fourth Program on Education, Training and Behavioural Change.

If successful Bronwyn Laycock will become Program Manager of Program 1, the largest program within the bid with a budget of $45.451M. The CRC will fund $150K per annum for a Program Manager to support this role, who will sit within the Dow Centre. In addition, there will be further activity for the Dow Centre around techno-economic evaluation of technology combinations for waste transformation ($50K per annum minimum). Additional projects will be fed to the Dow Centre through a collaboration with DAF Qld, particularly in the area of techno-economic evaluation, although this is not a fixed budget at this point.

Other activities for UQ, into which the Dow Centre may have a contribution, include a project with Queensland Urban Utilities (QUU) on anaerobic co-digestion and a project with EcoFuel Innovation on waste transformation to diesel. There are additional activities planned in wastewater management, black soldier fly transformation of food waste, and composite manufacture from waste fibres. At this point, the leverage to UQ is of the order of 3.5 - 4 times.

An announcement will be made in 2018.

Key people involved in project

Bronwyn Laycock, Joe Lane (plus others at UQ).

Future Fuels CRC Bid

Background

The Future Fuels Cooperative Research Centre aims to enable the transition to clean fuels for Australia's electricity, transport, agriculture, mining, construction and industrial sectors. Significant opportunity exists to adapt existing gas infrastructure for the production, transport, storage and use of more sustainable "future fuels" such as hydrogen, biogas and liquid derivatives like ammonia and methanol that can meet a significant part of local demand and generate export opportunities. The total value of the bid is $90 million over 7 years (cash and in-kind), with a cash request to the CRC of $26.25 million and total case commitments from the participants of $16.6 million. Participants include 4 industry, 6 University, 2 regulators and the Australian Energy Market Operator.

The CRC is structured around four programs of activity:

Program 1: Future Fuel Technologies, Systems and Markets – addresses technical, policy and commercial barriers to the increased utilisation of new low-carbon fuels and aims to accelerate development of production technologies and end-use applications.

Program 2: Social Acceptance, Public Safety and Security of Supply - studies the social and policy context within which future fuels technology and infrastructure operates.

Program 3: Network Lifecycle Management - addresses novel materials, design, construction, operations and maintenance for new infrastructure, and issues associated with re-purposing or decommissioning of existing gas networks that aren't suitable for future fuels.

Program 4: Education and Training Program – aims to improve the capacity of business, industry and research entities in the energy sector to participate in major collaborative research projects; develop the professional capabilities of new entrants into the industry to contribute to the delivery, management and leadership of research and application; and improve the capacity of the energy sector to understand complex problems, and how to influence policy and regulatory interventions to achieve successful industry development.

The Dow Centre will participate in Program 1 and other UQ participants will participate in Programs 2 and 4. Prospective Dow Centre projects will investigate and demonstrate at laboratory scale, novel processes for the production of near-zero CO_2 hydrogen and fuels from natural gas. The approach utilises methane pyrolysis in molten metals and salts. Outputs include process models and designs, techno-economic models, breakeven production cost analysis for a commercial plant and a basic engineering design for a pilot-scale field demonstration plant.

Announcements are expected mid-March 2018.

Key people involved in project

Simon Smart, Chris Greig, Khuong Vuong (plus others at UQ).

DOW Centre events, engagement & partnerships

The Dow Centre prides itself on undertaking and being involved in a diverse outreach program that encourages knowledge transfer through events, engagement and partnerships. Through our outreach programs we aim to showcase our research while engaging our expertise to encourage and facilitate debate that is constructive and informed, and adds a greater understanding of what is being undertaken at our research institute. This is both in line and complementary to our organisational mission: to foster and facilitate innovations in economically and environmental sustainable processes for energy, water, food and chemicals.

2017 saw the Dow Centre staff involved in 33 diverse events. Just under half of these events were public events allowing involvement by the general public. Three events were held at the Queensland Museum in August 2017. This trilogy of events under the banner of UQ Energy – It's all about energy, through a panel discussion sought to provide an energy state of the nation discussion, asking the question on the future of coal, how far we can go with renewable energy, and the roles that nuclear, pumped storage, gas and interconnections could play. The events were attended by over 1000 people from academia, green industry and the general public.

Key activities

EVENTS

The Dow Centre in 2017 was involved in 33 domestic events including 12 internal seminars with the aim of sharing and encouraging peer to peer knowledge. Eight internal workshops provided a greater hands on discussion and dialogue to share knowledge, especially to the students and higher degree students within the Centre. A further 12 public events ranging from public seminars, and panel discussions were held. A movie screening was a unique way to encourage thinking on energy alternatives.

CENTRE ENGAGEMENT

The Dow Centre's staff was involved in over 40 domestic and international engagement events in 2017. This includes media interviews and attendance at conferences and public seminars in which research was presented and policy discussions facilitated. Centre members attended nine major international meetings.

GLOBAL PARTNERSHIPS The Dow Centre enjoyed working with ten international collaborators from the USA, Canada, China, India, New Zealand, Kuwait and Germany. Representatives from these organisations visited the Down Centre or vice versa, our researchers visited their institutions.

EAIT Postgraduate Conference 2017

The annual Faculty of Engineering, Architecture and Information Technology Postgraduate Conference provides an opportunity for students to present their research, learn what other projects are studied and to meet fellow students from other schools and disciplines within the Faculty.

The theme of the 2017 conference was Innovation and Entrepreneurship. The Dow Centre sponsored the event with two separate awards, one for best innovation in the field of sustainability, the other for best innovation in the field of Entrepreneurship. Dow Centre director Prof Chris Greig gave the opening address.

Following are the abstracts of winning submissions for the Dow Centre Awards:

The Dow Centre best innovation in the field of sustainability award

First Place: Xin Fan, School of Chemical Engineering, *New generation of energy storage beyond lithium ion batteries*

The safety concerns with dendrite formation of lithium as anode highly limit the application of lithium batteries in energy storage. Therefore, developing new generation batteries that perform beyond this limit is promising. Magnesium rechargeable batteries (MRBs) based on metallic Mg as anode is an ideal alternative, because of their dendrite-free nature and cost reduction due to the natural abundance of Mg. The plus-two charge within each ion transfer leads to higher energy density than the lithium ion batteries. Further, the hybrid batteries using more efficient ion intercalation chemistry, such as Li^+, to replace the kinetically sluggish Mg^{2+} in cathode can solve the inferior performance of MRBs. We demonstrate a MoS_2/graphene composite as a cathode for Mg-Li hybrid batteries, which displayed a favorable reversible capacity with a high energy density. The combination of fast cathode kinetic and safe Mg anode is one-step towards building a safe and high-density energy storage system

Second place: Songcan Wang, School of Chemical Engineering, *Synergistic crystal facet engineering and self-doping of $BiVO_4$ photoanode for enhanced photoelectrochemical water splitting*

The Dow Centre best innovation in the field of entrepreneurship award

First Place: Andrew Job, School of Mechanical and Mining Engineering, *Real-time shovel mounted coal or ore sensing*

Characterising coal or ores in-pit and in real-time presents a significant value opportunity for the mining industry. Hyperspectral imaging systems are proposed as an enabling technology to achieve this real-time characterisation. This paper considers the application of a hyperspectral imaging spectrometer mounted on a shovel. We define the performance requirements for such a spectrometer and associated subsystems during a typical dig-load cycle. The relatively high swing rotation speed of the shovel requires approximately video-rate exposure times to achieve good spatial resolution. We analyse a selection of components against these requirements and find that suitable commercial spectrometers, detectors and optics appear fit-for-purpose. Automated, real-time spectral classification systems are also available, with only relatively modest requirements for processing power. We argue that at near peak solar illumination, a field deployable system is viable.

Second Place: Yousef Alqaryouti, School of Civil Engineering, *digital-fabrication structures for modular prefabricated infrastructure*

SISCA Competition 2017

The Dow Centre's 2017 SISCA competition was again complemented with the Dow Centre for Sustainable Engineering Innovation Start-up program (SEIS). The number of submissions rose by 50% compared to 2016, indicating a growing interest from UQ's student entrepreneurs. The finals took place in October 2017 in front of a jury with representatives of UQ, Dow Chemical and ILab.

Project: The Deployable House

Mr Yousef Al Qaryouti won first prize with his project "The Deployable House". He received the $12,500 SISCA cash prize as well as the Dow Centre Business Proposition Grant of $12,500. Previously in 2016, his team was awarded a Dow Centre Early Concept Grant which had provided the funds to further develop the project into this year's winning submission.

Can you tell us in one or two sentences what your project is?

The project idea is to develop a new prefabricated house design using digital fabrication technology by subdividing the house structural system into components that are easy to cut by computer-controlled machines and easy to assemble by non-skilled people. The house retains the streamlined construction of existing prefabricated systems and can additionally be rapidly fabricated with nonspecialist and low cost manufacturing plant.

In 2016 you won an Early Business Proposition Grant that you used to develop your prototype and submit a proposal for the main SISCA prize in 2017. What experience, feedback did you take form last year and use to improve your design and/ or business plan?

The design of the folded sandwich house started by developing several prototypes of 1mm cardboard using press-fit joints for the deployable system to test the new design concept. The proposed design was to be flat-packed for easy transport and could be rapidly assembled on site to create a robust structure. The feedback received from the judges was very helpful. Main comments were related to waterproofing, fire resistance, structure stability, and industry specifications and requirements.

The Dow Centre fund was used to investigate other types of materials. Plywood was selected as a primary building material since it is a sustainable, durable and light material. The design was further improved and tested since then and a small arch was constructed to investigate hybrid material (plywood with a reinforced polymer layer), joints behaviour and structural capacity. The prize allowed us to develop our small-scale prototype into a large-scale version ready to use in real-life.

Is the deployable house now ready to be used in a real situation or does it require further development?

Currently, structural investigations are underway on the large-scale prototype to confirm the design concept and performance of the structure. This will allow further understanding of the structural performance under natural lateral loading (wind/earthquakes) so that engineering certification for the product can be obtained.

In addition, the current house prototype is not provided with electrical, mechanical and plumbing services. Solar panels, lighting system, and a hot/cold water system still need to be incorporated in the house.

Once these tasks are finished the house will be ready for the market.

What is the next step? How will you use the prize money and business grant?

The deployable house provides a low-cost and rapid post-disaster housing construction. The house is environmentally friendly and can be easily assembled and constructed by non-skilled people. It can be used by governments and NGO's to quickly build durable shelters for those affected by natural disasters, refugees or the homeless.

The SISCA award will be used to bring the product on the market. It will pay for business registration, IP protection, two new prototypes (one for us, one to be sold by Maddel/ World Vision), two field deployments (one at UQ, one via a partner), and engineering certification.

Where do you want the project to be in a year or two years from now?

I look forward to deploy this product as a housing solution after natural disasters in Australia in particular and the world in general.

I can also imagine the house being used as a solution by those who, because of surging house prices, are struggling to find suitable housing. At $175/m^2, the deployable house is twice as affordable as its nearest competitor in the prefabricated housing market and will provide access to affordable housing for a large group of people.

It is my hope that two years from now our product will be on the market.

Do you have any advice for fellow SISCA participants or young student entrepreneurs in general?

The SISCA competition is a great chance for engineering students and entrepreneurs to pitch their business ideas and to win funds to develop their product/service into a business. In addition, the competition provides the opportunity to network with other entrepreneurs and people who can help to promote your idea into the business market.

Deployable house, outside (left), inside (above).

Project Title: A low cost environmental monitoring sensor system

The low cost environmental monitoring sensor system is a low cost sensor network available to mesh into the internet of things or a private network. The benefit is creating a greater spatial coverage for environmental monitoring and management decision making purposes.

Lead student Nathaniel Deering found that the greatest learning experience was the realisation that development of a start-up has to be a passion not a job. The financial restraints of development and bringing an idea to market are substantial and should be critically assessed, as wages or reimbursements are not achievable.

Nathaniel also enjoyed exploring all the work being conducted within EAIT. The early concept grant ideas were innovative and showed that STEM students are passionate about sustainability and want to address the current challenges from the development of biomedical wearables to confronting homelessness in Australia.

The project is developing well and the environmental sensors have continued to be deployed since the SISCA competition, with plans to transition onto the internet of things and real-time monitoring as envisioned in the original project scope.

Project title: Origami aircraft fuselage

This project aimed at applying origami technology to manufacture aircraft fuselage or the whole aircraft. The advantages of origami aircraft fuselage include high manufacturing accuracy, simple procedures, low material usage, fast construction etc.

The team has three PhD students from the field of origami research. While the students enjoyed the project from a development perspective, it did not provide a real insight into the business aspect.

The students believed that the competition itself was a great opportunity to meet people and share many interesting ideas, with valuable suggestions coming from the audience and fellow competitors.

The project has a long-term goal. Currently, the team is working on the relative origami research. They will manufacture a small-scale sample before the end of 2018.

EARLY CONCEPT GRANTS AWARDEES:

- Nathaniel Deering - A Low Cost Environmental Monitoring Sensor System
- Daniel Hubbard & David Nelson - POWERCUBE
- Sasikrishna Reddy K., John Malise Pathi, Abinav Kumar and Sangameshwaran - Organic Waste Compacting Bin
- UQ Folded Structure Group: – Quan Shi, Weiqi Cui and Ya Ou - Origami Aircraft Fuselage
- Abe Green & Max Bankowski - PODS in the Park
- Duy Huu Nguyen and Son-Duy Tran – Sustainable Concrete Road Pavement Design
- Emily Critchley, Emi Ariga, Huong Do, Samuel Williams and Tobias Jukes – The D-Tector
- Rynhardt Grove – Advanced Agriculture, Modularised Greenhouses for Sustainable Agriculture

International workshop on Energy and Development, organised by the Energy and Poverty Research Group

The United Nations, through its Sustainable Development Goal 7, calls for action from governments, practitioners and the research community to address the world's energy poverty challenge. The University of Queensland (UQ) responded to the call by establishing the Energy and Poverty Research Group (EPRG) in 2014. The group brings together interdisciplinary and innovative research capability to facilitate sustainable and affordable modern energy solutions in energy impoverished communities, with a particular focus on India and the Pacific.

Through its committed focus on field-based research, EPRG has developed a strong network of international partners and collaborators, particularly in India. Over time, however, it emerged that these partners, whilst mostly based in India, and working on various aspects of the energy poverty challenge, had had limited previous engagement with each other. EPRG arranged the workshop to bring together its Indian partners to strengthen the collaboration and align our efforts to help overcome India's energy challenges.

With this in mind, EPRG, with support from UQ's Global Engagement Office, organised an 'International Workshop on Energy and Development' on 9 December 2017 at the Indian Institute of Technology Bombay (IITB) in Mumbai, India. The primary purpose of the workshop was to bring an interdisciplinary group of Indian and Australian energy poverty researchers together to make introductions, share knowledge and experiences in addressing India's energy challenges, and identify collaborative opportunities moving forward.

In total, 31 researchers attended the workshop, representing more than eleven institutions, including academia, policy think tank organisations, and the Australian Government's Ministry of Energy and Environment. Together, the participants had disciplinary expertise and project experience in 20+ areas including, but not limited to, climate science; energy statistics; thermal and renewable energy engineering; business and management; social science, including gender studies; policy, regulation and governance; agriculture; energy economics; rural electricity access; energy inequality; environmental ethics and consumption; micro-grids; corporate social responsibility; and distributed energy planning.

The workshop began with student presentations that articulated a range of energy poverty facets, as they manifest in India. This was followed by streamlined group discussions on five targeted themes that encompass the policy, research and practice of energy for development in India. These themes included: climate and energy, gender and equity, role of the private sector, energy for productive livelihoods, and energy for community development.

Overall, it was a great first attempt whereby Indian and Australian researchers demonstrated solidarity in reinstating the value of a collaborative bilateral relationship in addressing one of the biggest issues of social and economic concern for India.

A key outcome of the workshop was a proposed visiting student program for second semester 2018. Applications from Indian students were invited in January 2018. Two PhD students from different Indian institutions were successful and will receive a fully-paid scholarship to visit EPRG for three months to work on a collaborative project as part of their current research.

Also, as a direct result of the workshop, EPRG is submitting a proposal seeking funding under DFAT's Australia India Council Grants Scheme. EPRG is proposing to strengthen its academic collaboration with Indian partners by organising a 'Summer School on energy access challenges in India'. The school will bring together up to 10 Australian and 20 Indian PhD students for an intensive 2-week classroom- and field-based study on energy and development in India in late 2018 or early 2019.

EPRG acknowledges the financial support from UQ's Global Engagement Office and the Dow Centre for Sustainable Engineering Innovation. This support was critical in enabling a wide range of participants from across India as well as EPRG's staff and student representatives to attend the workshop.

Events & media

Events hosted or sponsored by the Dow Centre and UQ Energy Initiative	
	Public Event, hosted by Chris Greig Energy State of the Nation (QLD State Library)
	Public Event, hosted by Chris Greig Reports on Energy (Qld State Library)
	Public Event, speakers - Chris Greig & Simon Smart Big Picture Energy or Energy after Dark (QLD Museum)
	Public Panel Discussion, Prof Simon Bartlett & Adjunct Prof Jim Snow "An overview of Australia's power system drivers - power system security and volatility of whole-sale market prices; and Queensland's role in Australia's transition to a low carbon economy"
	Public Seminar, sponsored by UQ Energy Initiative Renewable energy in competitive electricity markets - a three-act play.
	Public Seminar, sponsored by UQ Energy Initiative Moving towards a clean energy future in China: RD&D at NICE"
	Public Seminar, sponsored by UQ Energy Initiative Can Australia keep excluding nuclear power forever in a post-Finkel world?
	Movie Screening, sponsored by the UQ Energy Initiative Switch
	Public Seminar, sponsored by UQ Energy Initiative World energy special report: The southeast Asia Energy Outlook 2017. (Customs House)
	Public Panel Discussion, sponsored by UQ Energy Initiative The impact of power costs on Queensland and what can be done? (QLD State Library)
	Industry Engagement Breakfast, sponsored by UQ Energy Initiative Prospects for global energy markets and their implications for Australia (Brisbane Convention & Exhibition Centre)

Media and guest lecturer appearances	
	Chris Greig, ENGY4000-Australian Energy Policy, Guest Lecture
	Chris Greig, Carbon Budgets and Stranded Assets, Webinar
	Chris Greig, Energy Security and Prosperity in Australia, 2x Webinar for Global CCS Institute
	Chris Greig, Energy Sector Investment Decision making and Finance, Lecture for MBA students & Ministry of Energy & Mineral Resources, Indonesia
	Chris Greig, On & Off the Grid: Australia's Energy Future - World Science Festival, Panel Discussion
	Chris Greig, EPIA Executive Briefing: Implications of the Finkel Review, Panel Discussion
	Chris Greig, HRD Student Orientation, Panel Discussion
	Chris Greig, UQ Latin America Colloquium, Panel Discussion: Transforming global energy solutions
	Chris Greig, Australia should embrace nuclear energy, Debate
	Chris Greig, ABC Radio, Telephone interview - energy security
	Chris Greig, ABC, Sydney, Four Corners interview with Michael Brissenton
	Chris Greig, Daily News, Telephone Interview
	Chris Greig, ABC Canberra Radio, Live Telephone Interview on Commonwealth Governments policy for CCS under the Clean Energy Finance Corporation.
	Chris Greig, Washington Soul Pattison, Rapid Switch Pitch to the Board
	Chris Greig, ENGG7600, Guest Lecture
	Bronwyn Laycock, Carbon Fibre production from novel starting materials, invited lectures, Kuwait Institute of Scientific Research.
	Eric McFarland, ENGY4000-Nuclear Power, Guest Lecture

Visitors and travel

Representatives from the following organisations visited the Centre

Andlinger Centre for Energy and Environment, Princeton University
Australian Department of Industry Innovation and Science
BAEconomics Pty Ltd (CEO, Managing Director)
Carnegie Mellon University
Exergen Limited
Fraunhofer Institute, Germany
IIT-Bombay, India
Macquarie University
National Institute of Clean and low carbon Energy (NICE), Beijing, China
The University of Melbourne
University of Calgary, Canada
University of California, Santa Barbara, USA
University of Sydney

Centre members visited the following institutes/companies

Bluescope, Port Kembla, NSW, Australia
Carnegie Melon University, Pittsburg, USA
Exxon
IIT Mumbai, India
Intstitut of Teknologi Bandung, Indonesia
Kuwait Institute of Scientific Research
Monash University, Victoria
National Institute of Clean and low carbon Energy (NICE), Beijing China
NIAS and Indian Institute of Science, India
Norske Skog, Tasmania
Princeton University, USA
Selco Foundation, India
Tata institute of Social Sciences, India
University of California, Santa Barbara, USA
University of Adelaide, South Australia

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
Australian Institute of Bioengineering and Nanotechnology
Centre for Coal Seam Gas,
Centre for Policy Futures
Global Change Institute
School of Agriculture and Food Science
School of Chemistry and Molecular Biosciences
School of Information Technology and Electrical Engineering
School of Social Science
School of Public Health and Social Work
School of Communication and Arts
UQ Energy Initiative

Australian collaboration partners

Adelaide University, South Australia
Deakin University, Victoria
James Cook University, Queensland
Manildra Group
University of Southern Queensland, Queensland
University of Tasmania, Tasmania
Qld Government Department of Agriculture and Fisheries (DAF)
Queensland University of Technology, Queensland

International collaboration partners

Ashoka Trust for Research in Ecology and the Environment (ATREE), India
Andlinger Centre, Princeton University, USA
Carnegie Melon University, Pittsburgh, USA
Fraunhofer Institute, Germany
Georgia Institute of Technology, USA
IIT-Bombay, India
Kuwait Institute of Scientific Research, Kuwait
National Institute of Clean and low carbon Energy (NICE), Beijing, China
Scion Research, New Zealand
Tsinghua University, China
University of Calgary, Canada
University of California, Santa Barbara, USA

Teaching & learning

A key element of the Dow Centre's purpose is to help equip a new generation of thinkers with the capacity to contribute to the significant challenges to the 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.

The Dow Centre approach to teaching and supervision aims to encourage fresh ideas and that support innovators with potentially sustainable solutions to the major challenges in energy, water, food and chemicals.

Key activities

TEACHING
Centre staff take an active role in lecturing, mentoring and tutoring a number of UQ courses delivered within the Schools of Mechanical Engineering and Chemical Engineering.

SUPERVISION
In 2017 fifteen students were undertaking higher degrees with research topics that were part of a Dow Centre project and a further 19 students with higher degree research related to Dow Centre projects. Many of these were part of the Energy Poverty Group.

"Women in these poorer communities, who are generally the cooks and managers of household resources, are at the centre of this struggle."

Romy Listo in South Africa studying energy, gender equality and women's empowerment

Romy Listo joined the UQ Energy & Poverty Research group in January 2016 to study the relationship between energy, gender equality and women's empowerment. Although it was not her focus when she started her research, she became increasingly motivated by her passion for gender equality and what she came to see as a need for more research on women and gender equality in the energy field.

Outside of her PhD, Romy is active in the Australian women's sector and is an advocate for preventing violence against women in Australia, particularly young women. She teaches sexuality and respectful relationships education to young people, and is part of a group of young women based across Australia, known as YWAG (Young Women's Advisory Group), who are conducting community-based research and lobbying government to improve education as a tool for preventing gender-based violence.

As a child, Romy was already passionate about human rights and social justice. This led her to study social sciences and international development as an undergraduate student, and later study community development at a postgraduate level. Over that time, she volunteered in a range of community organisations, including a micro-enterprise program with a focus on women and energy technologies in rural Guatemala. Joining the Energy & Poverty Research Group brought her passions for development work, gender equality, and her academic skills together with the unlikely focus of energy.

Romy is now in South Africa for six months collecting data for her research. South Africa continues to face challenges with providing basic services to its poorer communities. The ongoing racial, class and gender inequalities make it a rich context for studying how energy justice and gender equality are intertwined. Although South Africa has made massive strides towards electrifying the country since the end of apartheid, poorer communities continue to struggle to pay for electricity, and in reality, rely on a range of fuels for their household need. These fuels are neither safe, healthy nor affordable, and include a mix of paraffin, candles, and fuelwood, as well as electricity.

Women in these poorer communities, who are generally the cooks and managers of household resources, are at the centre of this struggle. With her research, Romy hopes to bring the daily realities of these women, and the solutions they create to gender inequality and energy poverty, to the attention of researchers and policy-makers. She also hopes to record this knowledge in a way that's useful for these women on the ground.

At the moment, Romy's biggest day to day challenge has been learning to live amidst the stark differences in people's worlds, from informal shack settlements to the waterfront holiday homes, that continue to make Cape Town one of the most unequal cities in the world.

After finishing her PhD, Romy hopes to continue her work on the overlap between natural resources and gender equality. She values the balance of practice and theory which field-focused research can bring, and would like to work for a women's development agency or continue in academic research.

Professional Practice in the Business Environment

Dow Centre director Professor Chris Greig conceived, developed and teaches ENGG4900 Professional Practice in the Business Environment.

First offered in 2013, it is available to final year engineering students. Initially intended as an elective leadership course targeting a class size of 35, the course has proven to be extremely popular with enrolments growing rapidly from 55 in 2013 to 463 in 2017.

ENGG4900 has a multidisciplinary approach, introducing engineers to the 'non-engineering' factors (enablers and barriers) that influence the delivery, uptake and investment prospects of engineering technologies and projects.

Students learn to:

- Recognise and address technical, economic, regulatory, social and environmental issues, and to assess risks and uncertainties encountered when deploying technologies or implementing projects.
- Evaluate the financial feasibility of projects and evaluate the impact of important risks and uncertainties on project outcomes; and to
- Develop strategies and tools to mitigate risk and reduce uncertainty, and implement technological change within an overriding ethical framework for better-quality business decisions.

Ethical considerations feature prominently throughout the course, teaching students to recognise the conflicting objectives and values of multiple stakeholders (including oneself), and the challenges such conflicts present to decision making in professional practice.

In addition to traditional and on-line lectures, students receive guest lectures from experienced and successful business leaders and participate in discussion forums and workshops. Assessment is case study based with students working mainly in teams under the guidance of mentors.

In 2017 the program was expanded to include two new masters-level multidisciplinary courses for international students:

- ENGG7901 which focusses on professional practice from a project development perspective; and
- ENGG7902 which focusses on professional practice from an innovation and entrepreneurship perspective.

Energy Systems

ENGY4000 Energy Systems is a 4th year engineering elective for Chemical and Mechanical Engineering students. It was developed and implemented in 2016 by Dr Anand Veeraragavan (School of Mechanical Engineering) and Dr Simon Smart (Dow Centre) who previously ran concurrent, discipline specific courses on the growing challenges delivering energy to a world facing the growing reality of climate change. Such challenges require multi-disciplinary teams who can not only design and critique the technical aspects of new energy systems but also evaluate their economic, environmental and social impacts and effectively communicate outcomes to multiple stakeholders. The curriculum is project-centred with students asked to develop sustainable energy solutions. In 2017, the project required students to present a zero CO_2 plan for powering a remote LNG facility and associated community. This is supported by traditional lectures, readings and tutorials, as well as guest lectures from industry and academic experts who provide both in-depth content but also wider picture perspectives on policy, markets and social issues. The course has maintained about 100 students each semester with great feedback, particularly about the focus on real-world problems and the need for considering holistic solutions.

ENGY7000 Energy Principles and Renewable Energy is the introductory course for the Masters of Sustainable Energy program. Developed by Dr Simon Smart in 2012 for the Masters of Energy Systems, ENGY7000 underwent a transformation in 2017 to focus on renewable electricity generation. Taught intensively over a full week, the course is offered in both Semester 1 and 2 to around 20 students per class. The course is structured in modules and the small class size promotes extensive interactions between the cohort and the lecturer as well as amongst the students themselves. Traditional lectures are broken up with individual and group activities and the week concludes with a series of group presentations - roleplaying countries in climate negotiations similar to the Paris Climate Agreement. The Semester 1 offering is preceded by a weekend induction in Gladstone where students visit industrial sites to gain an appreciation for the enormity of the energy / climate challenge.

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

Centre member	Role	Course code
Bronwyn Laycock	Lecturer and Tutor	CHEE2010, Semester 2, Engineering investigation and statistical analysis
Mojgan Tabatabaei	Mentor	CHEE3020, Semester 1, Process system analysis
Bronwyn Laycock	Lecturer and Tutor	CHEE3301, Semester 1, Polymer engineering
Mark Hodgson	Tutor	CHEE4001, Semester 2, Process engineering design project
Sara Zeinal Zadeh	Project leader	ENGG1200, Semester 2, Engineering modelling and problem solving
Simon Smart	Lecturer and mentor	ENGY4000, Semester 1, Energy systems
Brett Parkinson	Tutor	
Ben Kefford	Tutor	ENGG4900, Semester 2 Professional practice and the business environment
Chris Greig	Lecturer and course co-ordinator	
Simon Smart	Lecturer and course coordinator	ENGY7001, Semester 1, Energy principles and renewable energy
Chris Greig	Lecturer	ENGY7004, Semester 1, Energy, finance and investment.
Stephen Wilson	Lecturer	ENGY7117, Semester 2, Energy markets law and policy (MES intensive)
Sara Zeinal Zadeh	Tutor	ENGG7601, Semester 2 Experimental design
Simon Smart	Course coordinator and lecturer	ENGG7902, Semester 2, Engineering innovation and leadership
Luigi Vandi	Supervisor	MECH4500, Semesters 1 and 2, Engineering thesis

The Centre staff supervise 53 students

Student	Supervisor	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 Mark Hodgson (PhD)	Dr Simon Smart	A global transition to low carbon economy - limits of possibility ?
#Ms Xia Huang (PhD)	Prof Lianzhou Wang Dr Bin Luo Dr Ruth Knibbe Prof Eric McFarland	Design of new two-domensional hybrid materials for lithium sulfure batteries
#Mr Edward Jiang (PhD)	Prof Darren Martin Dr Pratheep Annamalai Dr Bronwyn Laycock	Water-based processing of spinifex nanocellulose fibrils into continuous textile fibers
#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 Jenny Munro Dr Peter Westoby Prof Chris Greig	Power to empower? Exploring the role of energy in women's organising and empowerment in rural India
#Mr Yuwan Malakar (PhD)	AsPr 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 Francois Visser Dr Bronwyn Laycock	Next-generation fertilisers for nutrient stewardship
#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
#Mr Kushagra Bimalbhai Bosamia (Ugrad Thesis)	Dr Simon Smart Dr Rijia Lin	COx free Hydrogen Production using Membrane Reactors and Methane Pyrolysis
#Mr Zachary Brown (Ugrad Thesis)	Dr Simon Smart Mr Brett Parkinson Mojgan Tabatabaei	Techno-Economic Analysis of Electrolytic Magnesium Production via Process Coupling
#Mr James Hammett (Ugrad Thesis)	Dr Simon Smart Mr Brett Parkinson	Methane pyrolysis carbon by product economic evaluation
#Ms Candice Haverfield (Ugrad Thesis)	Dr Simon Smart Mr Brett Parkinson	Methane Pyrolysis for CO_2-Free Power Production and Hydrogen Generation
#Ms Genevieve Russell (Ugrad Thesis)	Dr Simon Smart Mr Brett Parkinson	METHANE PYROLYSIS FOR CARBON DIOXIDE-FREE POWER PRODUCTION
#Yee Yun Chung (Summer Research Program 2017/18)	Dr. Simon Smart Brett Parkingson Mojgan Tabatabaei	the Alternative Pathways for Ammonia Production project
*Heidi Cooper (PhD)	Prof Karen Hussey Prof Chris Greig	The rise of the disempowered citizen and its impact on the development of effective responses to the Climate-Energy nexus

The Centre staff supervise 53 postgraduate students

Student	Supervisor	Project Title
*Ms Heidi Cruz (PhD)	Dr Ilje Pikaar Dr Bronwyn Laycock Prof Paul Lant	The fabrication and use of hydrogels as an innovative and cost-effective approach for targeted recovery of reactive nitrogen
*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
*Ms Leela Dilkes-Hoffman (PhD)	Dr Bronwyn Laycock AsPr Steven Pratt Prof Paul Lant	The development and sustainability analysis of high-performance, multi-layered, biodegradable food packaging
*Mr Johannes Grove (PhD)	Prof Paul Lant Dr Simon Smart Prof Chris Greig	Energy transitions in developing countries and the role of alternative liquid fuels in reducing energy poverty
*Mr Amir Nemati Hayati (PhD)	Prof Darren Martin Dr Pratheep Annamalai Dr Bronwyn Laycock Prof David Evans	Renewable textiles and foams reinforced with nanocellulose
*Mr Mattew Herrington (PhD)	Prof Paul Lant AsPr 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 AsPr Srinivas Sridharan	Private sector electrification in Base of the Pyramid marketplaces in India: opportunities for energy and business to create Shared Value
*Ms Amy Hodson (PhD)	Prof Peta Ashworth Prof Chris Greig	Understanding societal attitudes to low carbon technologies
*Mr Craig Jacobson (PhD)	Dr Simon Smart Dr Ananthanarayanan Veeraragavan Ms Vigya Sharma	Applying systems modelling to tackle energy poverty challenge
*Ms Pawarisa Luangthongkam (PhD)	Dr Steven Pratt Dr Bronwyn Laycock Prof Paul Lant	Biosynthesis of Polyhydroxyalkanoates (PHAs) in Methane-utilizing Mixed Cultures
*Mr Thanh Tung Nguyen (PhD)	Dr Michael Heitzmann Dr Luigi-Jules Vandi	Development of sustainable engineered structural panels
*Mr Andrew Pascale (PhD)	Prof Paul Lant Dr Simon Smart Prof Chris Greig	The links between energy and human welfare
*Mr Thomas Reddell (PhD)	Dr Ananthanarayanan Veeraragavan Dr Simon Smart	Biomass fired Supercritical Carbon Dioxide Power Cycles: Microgrid Applications and Modelling
*Ms Beatriz Reutter Susaeta (PhD)	Prof Paul Andrew Lant Dr Joe Lane	The environmental opportunities and consequences of reducing food waste
*Ms Syarifah Nuraqmar Syed Mahamud (PhD)	Dr Bronwyn Laycock Dr Steven Pratt Prof Paul Lant	Polyhydroxyalkanoate (PHBV) Copolymer Production using Methanotrophic Cultures

The Centre staff supervise 53 students

Student	Supervisor	Project Title
*Mr You Hsing Huang (MEng Thesis (coursework)	Dr Simon Smart Mr Brett Parkinson	Temporary off grid power generation for refugee camps
*Mr Semso Sehic (MSE Professional Project)	Dr Simon Smart Dr Diego Schmeda Lopez	Review of business models developed around the world for residential distributed energy uptake: Exposing the benefits and constraints for the Australian consumer and context
*Mr Budi Santosa Sukarno (MSE Professional Project)	Dr Simon Smart Ms Franziska Curran	Leapfrogging the Indonesian Energy System through Prosumerism
¤MS Gloria Monsalve Bravo (PhD)	Prof Suresh Bhatia Dr Simon Smart	Engineering models of permeation in mixed-matrix membranes
¤Ms Emilie Gauthier (PhD)	Dr Bronwyn Laycock AsPr Rowan Truss Prof Peter John Halley	Understanding and predicting environmental effects on degradation of oxo-degradable polyethylene blown films
¤Ms Nur Ab Hamid (PhD)	Dr Liu Ye Dr Simon Smart Dr David Wang	Forward Osmosis (FO) Membrane-based Technology in Urbane Wastewater Treatment
¤Mr Jarrad Humphry (PhD)	Dr Michael Heitzmann Dr Luigi Vandi AsPr Rowan Truss Prof Darren Martin	Reactive processing as a novel processing route for high performance compositive manufacture
¤Mr Christian Kudisonga (PhD)	Dr Luigi Vandi Dr Michael Heitzmann	Novel reactive transfer moulding of thermoplastic composite materials
¤Ms Charmaine Lamiel (PhD)	Prof Joao Diniz da Costa Dr Julius Motuzas Dr Simon Smart Prof Xiu Zhao	2D-3D Carbon Mixed Matrix Membranes
¤Mr Christopher McMahon (PhD)	Dr Simon Smart Prof Ian Cameron	Trace element modelling and optimisation in an integrated steel works
¤Mr Abdul Quader (PhD)	Dr Thomas Rufford Dr Simon Smart	Evaluation of pressure swing adsorption systems for CO_2 removal and liquefied natural gas production
¤Mr Gregory Siemon (PhD)	Dr Simon Smart Prof Ian Cameron	Enterpirse-wide optimisation in steelmaking
¤Ms Samira Siyamak (PhD)	Dr Bronwyn Laycock Dr Paul Luckman	Tailored starch based hydrogels: Renewable material solutions for wastewater and agriculture industries
¤Mr Armin Solemanifar (PhD)	Dr Bronwyn Laycock Dr Albertus Mostert Dr Tuan Nguyen	Bio-inspired conducting peptide nanowires
¤Mr Manh Tuan Vu (PhD)	Dr Simon Smart Dr Rijia Lin Prof Suresh Bhatia	Mixed matrix membranes for H_2/CO_2 separation

The Centre staff supervise 53 postgraduate students

Student	Supervisor	Project Title
¤Ms Siti Abd Jalil (MPhil)	Prof Joao Diniz da Costa Dr David Wang Dr Simon Smart	Investigation of Vacuum-Assisted Preparation Methods of Inorganic Membranes
¤Mr Chun Yip How (Edmund) (Intern from Ngee Ann Polytechnic, Singapore)	Dr Bronwyn Laycock	Novel fertiliser production using tailored silicons
¤Ms Yu Ting Huang (MEng Thesis (coursework))	Dr Simon Smart	Rapid thermal processing of silica membranes
¤Mr Myles Domjahn (CHEE7104 Placement)	Dr Simon Smart	Energy Efficiency & Heat Integration within the Gladstone New Fuels Development Project
¤Ms Michelle Heenan (MECH4500)	Dr Luigi Vandi	Flying Like a Bird!
¤Mr Oswaldo Segovia (MECH4500)	Dr Luigi Vandi	Flying Like a Bird!
¤Mr Jacob Skewes (MECH4500)	Dr Luigi Vandi	Next Generation Composite Sheets for Automotive Parts

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.
¤ Students whose subject does not relate to Dow Centre projects.

Publications

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Chan C.M.; Vandi; L.J. Pratt, S.: Halley, P.; Richardson, D.; A Werker, A. and Laycock, B.: "Mechanical Performance and Long-term Indoor Stability of Polyhydroxyalkanoate (PHA)-based Wood Plastic Composites (WPCs) Modified by Non-reactive Additives", European Polymer Journal, online Nov 2017, 98, 337 – 346. DOI: 10.1016/j.eurpolymj.2017.11.041

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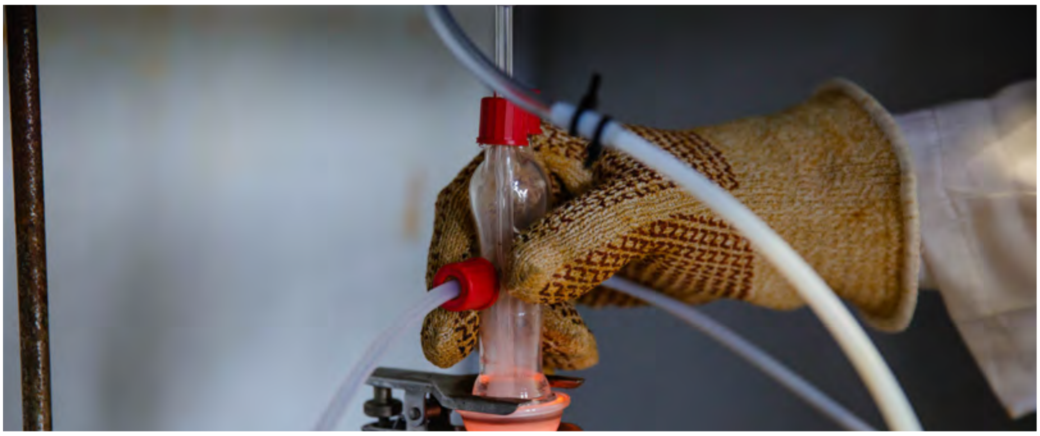

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