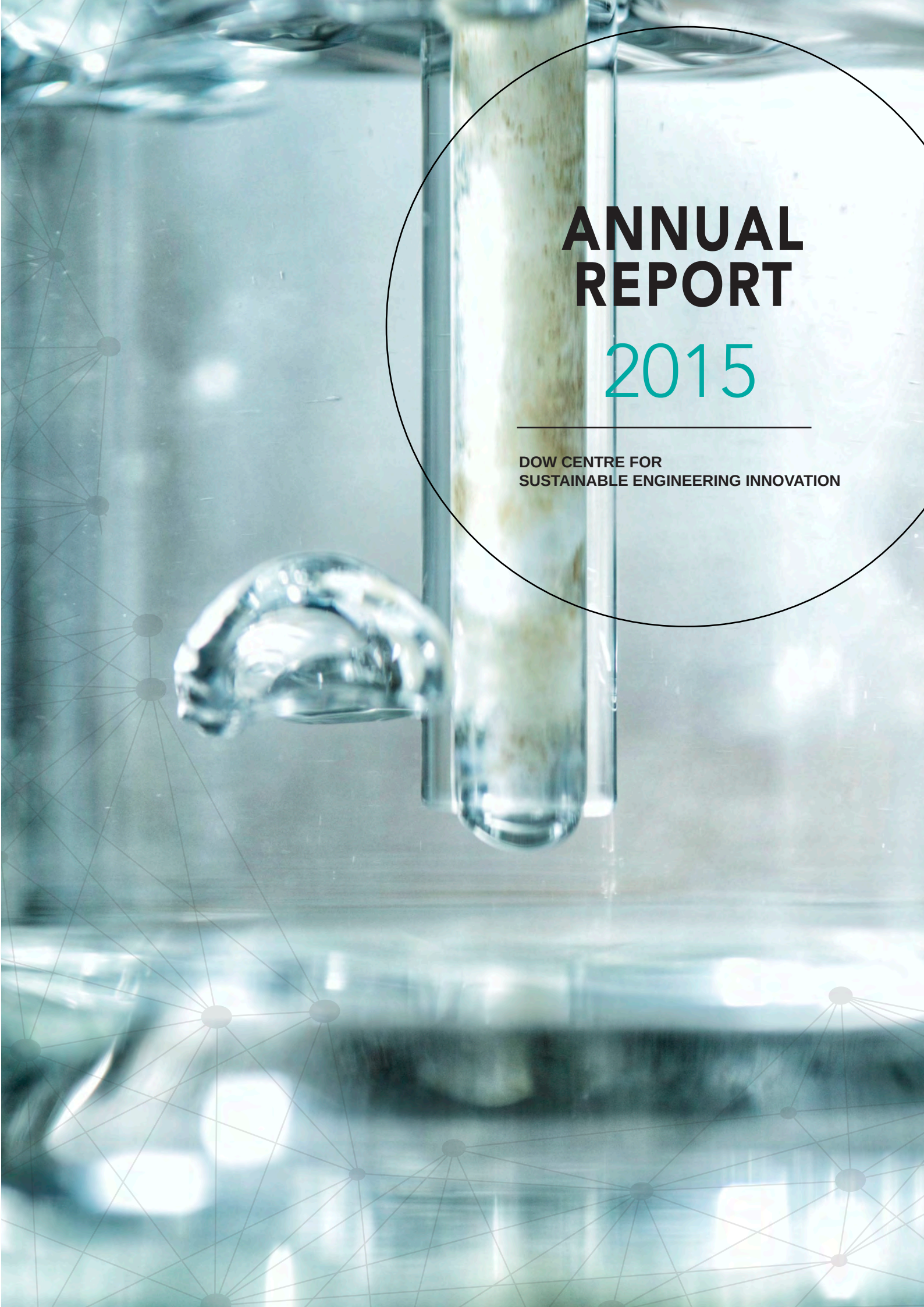


ANNUAL REPORT 2015

DOW CENTRE FOR
SUSTAINABLE ENGINEERING INNOVATION

.... to foster, identify, and facilitate innovations in economically and environmentally sustainable processes associated with the production and use of energy, water, food, and chemicals

Annual Report 2015

DOW CENTRE FOR
SUSTAINABLE ENGINEERING INNOVATION

THE UNIVERSITY OF QUEENSLAND
AUSTRALIA

CONTENTS

DOW CENTRE FOR SUSTAINABLE ENGINEERING INNOVATION

FOREWORD

On behalf of the Dow Centre Advisory Board, I am once again pleased to introduce the Centre's annual report.

Within The University of Queensland, the Dow Centre for Sustainable Engineering Innovation holds a unique position as a centre that not only excels in research, but combines creativity and critical thinking toward outcomes for true, economically viable innovation in technology. The Centre makes a valuable contribution to the University's mission to *Create Change*.

In many ways 2015 has been a year of development for the Centre, with many of the research projects, such as the Sustainable Carbon Fibre Production and Low Carbon Chemical Production projects, entering a stage where industry participation in further development can be sought. The Centre's approach is characterised by the conviction that true technological development can only be sustainable if it is economically viable and competitive. This applies particularly to the Centre's core projects in methane conversion, low-cost ultra-safe nuclear energy and materials innovation, with their ultimate goal of reducing the level of CO_2 in the environment through technology that is cost-competitive with existing practices.

The Centre fosters innovation through a number of avenues. It is particularly pleasing to see in this report the variety and depth of Centre initiatives that are helping to inspire and educate the next generation of future thinkers and innovators, such as the Centre's Pitch Program and the Sustainable Innovation Student Challenge Award (SISCA).

On behalf of the Advisory Board, I extend our sincere thanks to Professor Eric McFarland, who ended his tenure as the Centre's inaugural Director in December 2015. In guiding the Centre through its establishment and initial growth stages, he has created a solid techno-economic foundation on which his successors can build. Eric will continue to add vital support to the Centre as a consultant and collaborator with the UQ team on several core projects.

I warmly welcome the appointment of Professor Chris Greig as the Centre's new Director in 2016. His impressive record of contributions to the University and to the energy sector mean he is well-equipped to ensure the Dow Centre fosters innovations that create real change around the globe.

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 2015. Furthermore, I thank the Dow Chemical Company for its continued investment and support, which enabled the Centre to flourish in 2015.

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

The Dow Centre's approach is characterised by the conviction that true technological development can only be sustainable if it is economically viable and competitive

DIRECTOR'S REPORT

We work very closely with (and between) industry and university groups as well as with governmental agencies to help support work to overcome science and engineering hurdles

With increasing global prosperity, the interdependencies of economies, transportation, communication, and the growing demand for food, water and energy accelerate the need for practices and processes that are both economically and environmentally sustainable. The gathering of nations this year in Paris underscored the fact that among our greatest challenges are the sustainable production, transmission, storage, and use of low-cost fuels and electric power. It is likely that the costs of the environmental consequences of carbon dioxide released into the atmosphere have been underestimated and that continued reliance primarily on fossil resources is unsustainable, perhaps even in the near term.

There are no game-changing commercial solutions ready to bring about a rapid switch from a world powered by widely available, low-cost, fossil hydrocarbons, to a future with many more prosperous people powered by environmentally sustainable technologies, which are cost competitive. The Dow Chemical Company and The University of Queensland have generously dedicated resources to broadly support engineering innovation as a key contributor in ensuring a prosperous and sustainable future. Their support and their direct participation on our Board of Advisors reflect commitment to this important human challenge.

Centre mission and goals

The mission of the Dow Centre for Sustainable Engineering Innovation is to ***foster, identify and facilitate innovations in economically and environmentally sustainable processes associated with the production and use of energy, materials, water and/or food***. The Centre is working to promote activities that address major challenges and opportunities in support of global "Sustainable Prosperity" beyond the traditional industry development horizons.

Unlike most university-based sustainability initiatives, the Dow Centre at The University of Queensland has built a team skilled in conceptual process design and in techno-economic analysis to allow a top down approach to the evaluation of sustainability options. The Dow Centre supports applied research propositions that have passed a techno-economic and sustainability screening assessment and where the technical success of the research will likely contribute to enabling high impact processes of benefit to society. Once a compelling case has been made from a conceptual process model that assumes success in the research and technology development, then the science and engineering hurdles needed to enable the process are defined and prioritised for targeted research efforts. The Dow Centre, by design, works very closely with and between industry and university groups as well as with governmental agencies to help specifically support work to overcome those science and engineering hurdles.

The overall goals of the Dow Centre have been to:

1. Foster innovation and new ideas for high-impact processes contributing to the sustainable production and use of energy, materials, water and/or food.
2. Develop and apply quantitative methods for techno-economic, life-cycle and sustainability analyses for potential new processes.
3. Promote education, communication and cooperation globally to embrace evidence-based approaches to evaluating options for environmental and economic sustainability and recognise industry's key roles in enabling solutions.

Our strategy has been to:

- Promote engineering innovation globally and search widely to identify potentially game-changing process ideas related to large-scale sustainable production of water, food, materials and/or energy,
- Build conceptual engineering models and perform techno-economic, life cycle and sustainability analyses for new processes, using the best available methods (and our own new methods) focussing on technical and economic risk-based decision making and quantitative risk assessment,
- Identify the key scientific and engineering problems requiring solutions to enable the commercial deployment for high impact processes, which are found to be potentially economically and environmentally sustainable,
- Work to couple specific research groups with financial sponsors to conduct the work needed to overcome those scientific and engineering barriers to sustainable processes,
- Build core competency in the technical analyses as an academic centre, teaching and making the skills available to students and academic and industrial partners, and
- Create global relevance of the Centre through local and international outreach promoting public and private involvement and collaborations and greater awareness of the challenges in creating a sustainable and prosperous global society.

2015 highlights

During our second year of operation the Centre has progressed or completed several projects and programs initiated in year 1 and embarked on new initiatives.

Fostering innovation

A major role of the Centre is to identify means for stimulating innovation related to sustainability. In 2015 the Centre's activities included expansion of our "Pitch Program", which solicits proposals for addressing major challenges in global sustainability from inside and outside the UQ academic community. Last year the Dow Centre sponsored work in energy poverty, bio-processes and biomaterials. In 2015 we reviewed nine new proposals and selected one for funding that proposed examining the origins of STEM professionals' views on nuclear power and a second evaluating the extent of the true problem with electronic waste recycling. The Dow Centre organised and conducted the 2015 student competition for the Dow Chemical Sustainability Innovation Student Challenge Award (SISCA), which drew a variety of ideas from amongst the UQ student population addressing major sustainability challenges. The finalists had a range of novel ideas on building sustainability and the winning entry presented a clever means for a low-cost, sustainable shelter structure. The Dow Centre also helped shape the challenge and represented UQ in the 2015 Global Business Plan Competition, which this year drew over 60 entries from students from around the world addressing the future of food production. The $100,000 prize was awarded to a team from the University of Capetown who proposed a new integrated approach for efficient fish farming.

Techno-economic and sustainability analysis and research

The Centre continues to build core competency in conceptual process design and techno-economic analysis, and the team is engaged in a variety of technical evaluations of potentially important, sustainable technologies. In 2015 publications appeared from the Centre team on the technoeconomics of biofuels, flow batteries and solar hydrogen production in addition to scientific publications related to energy.

The majority of the efforts in 2015 were devoted to three primary topic areas.

Improving sustainability with new materials and materials processes has been a central theme in the Centre and our work, started last year, on innovative approaches to low-cost carbon fibre production continued in 2015 with support from the Dow Chemical Company for fibre synthesis from polyethylene and under a grant from the ARC for carbon fibres derived from nanocellulose. The Dow Centre team led by Dr Bronwyn Laycock in collaboration with researchers at the Australian Institute for Bioengineering and Nanotechnology (AIBN) at The University of Queensland have created a new chemical process option with significant promise for carbon fibre production from polyethylene and nanocellulose. Although the polyethylene based fibre program is completed, the nanocellulose work will continue into 2016 and the IP and publications related to the polyethylene process will be submitted.

Natural gas is a relatively low-cost and abundant worldwide resource. Present uses for fuel and chemicals involve oxidation with molecular oxygen. The Dow Centre team has been evaluating alternative processes and new oxidants that would make more efficient use of methane without CO_2 production. In one study to be completed shortly, the potential for small-scale methane-to-chemicals using different technology options was evaluated. The capital cost for any known conversion including biological or thermochemical will limit any small-scale application and does not suggest opportunities for major impact. The Dow Centre team has re-examined the costly process steps in presently practiced methane conversion and developed several alternative schemes employing non-oxygen oxidants that show promise in allowing large scale methane utilisation without carbon dioxide production. A comprehensive patent application was filed in 2015. The Centre has teamed up with experimentalists at the University of California to prove up several of the key chemical conversions steps in 2016.

Nuclear power is among the few proven technologies capable of producing the massive quantities of always-available, highly reliable electricity needed to power the mega cities of the future without producing carbon dioxide. Today's low-cost fossil fuels limit the competitiveness of nuclear power, nonetheless China, India and Russia are moving forward to

significantly increase their nuclear technology capabilities and installed base. The Dow Centre has been active in exploring new approaches to improving the value proposition of nuclear power. It has proposed novel chemical processes that make use of nuclear processes to allow co-production of valuable chemicals improving the economics of existing nuclear plants. More recently, we have examined ultra-low cost, ultra-safe reactor core designs with the goal of building nuclear reactors at a cost less than a coal power plant. Our strategy is to help provide real economic incentives rather than the less tangible, and far less compelling, climate related rationale alone to build and maintain expertise and competency in zero carbon nuclear power technology.

Education, communication and outreach

As part of the School of Chemical Engineering the Dow Centre's major commitment is to the education of students. Our team has been directly involved in teaching and in delivering academic seminars on topics related to the sustainable production of energy, materials, water and food. Several seminars and workshops were organised or co-sponsored by the Dow Centre in 2015 including the third in a series of international workshops on the Future Directions of the Chemical and Fuels industry and a workshop on energy storage. The Dow Centre also sponsored two internationally recognised scientists to attend meetings in Queensland and to visit UQ.

The Dow Visiting Fellows Program continued to attract applicants from top universities worldwide and in 2015 PhD students from Caltech, the University of California, Irvine, and Loughborough University came to the Dow Centre for several months, working with the Centre team on techno-economic evaluations related to their thesis research. Increasing collaboration and exchange of ideas between individuals from top international universities and industry teams and the UQ students and faculty are major objectives of the Dow Centre.

Into 2016 with new leadership

Entering into 2016 the Centre has had a change in leadership and we are fortunate to have Professor Chris Greig as our new Director as I resume a primary position in the Chemical Engineering faculty at the University of California, Santa Barbara. I am excited to have been given the opportunity by Professor Greig to remain active in the Centre's technical programs and continue to work with the exceptional Centre team. Professor Greig brings enormous industrial experience having built a globally successful process engineering company as well as holding senior executive and project director roles in the industrial and resources sectors both in Australia and abroad.

In the following paragraphs, Professor Greig gives his perspectives on the Centre and its priorities moving ahead.

It is indeed an honour to take on the role of Director of the Dow Centre for Sustainable Engineering Innovation. The Centre provides just the vehicle for UQ to make a positive contribution to the transformational changes that are happening across the global economy. As the world deals with compounding challenges of climate change, environmental degradation, resource security and population growth, engineering innovation will provide a vital thread in the sustainability challenge.

In the past this sustainability challenge, especially in relation to climate change, has been truly appreciated by few industrial companies. My observations of companies around the world have seen a shift over the past year though and I am noticing more and more large industrial companies who see sustainability as material to the company's future rather than an exercise in public relation management.

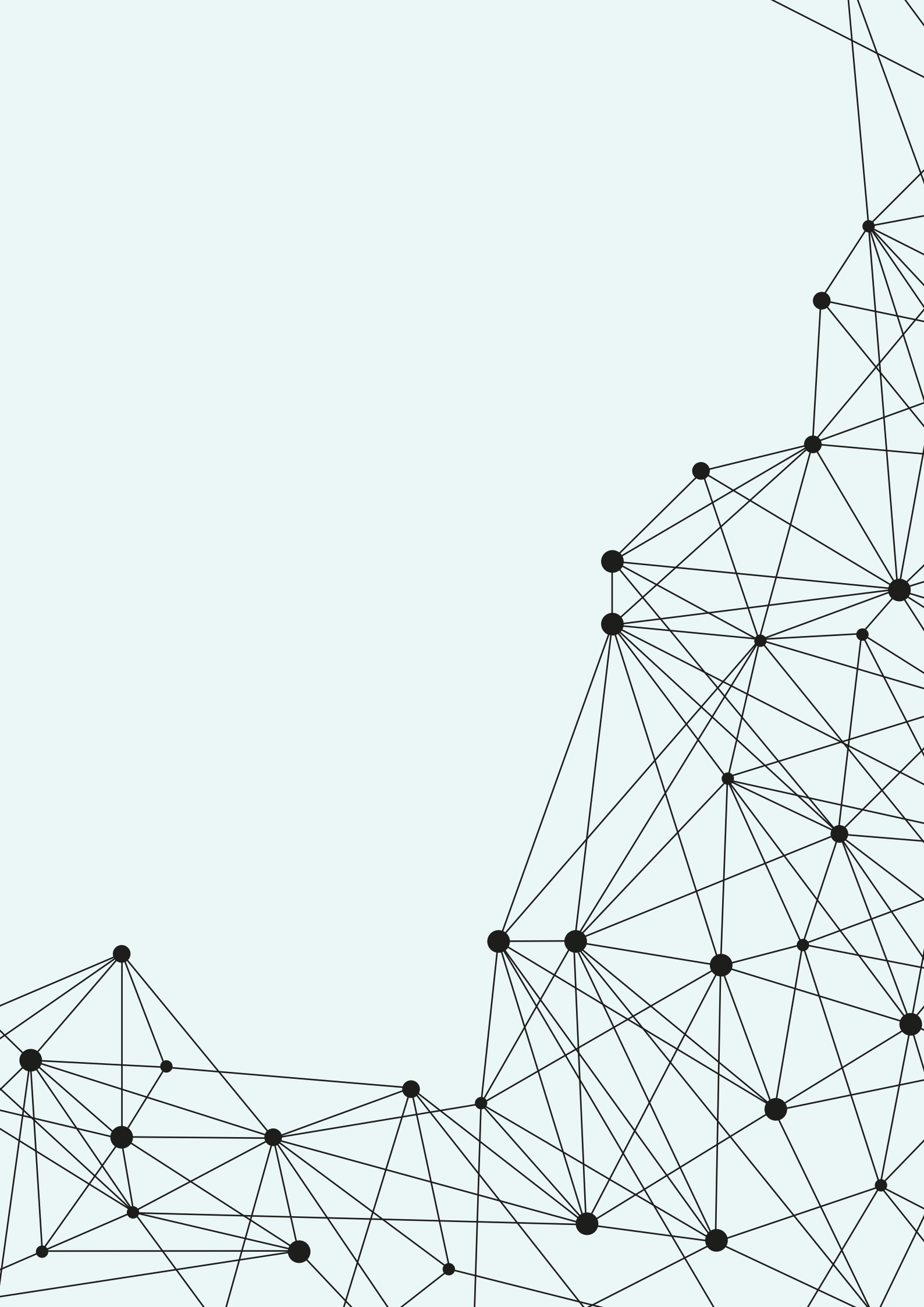
Outgoing Director, Professor Eric McFarland showed great vision by emphasising techno-economic performance alongside the environmental and social lenses that often drive the sustainability agenda. Naturally I plan to maintain this thrust with a continued focus on the sustainable production and utilisation of energy, water, food and materials. I'm looking forward to continuing to work with the small team of very motivated, bright young scientists and engineers at the Centre but also to continuing and extending the working relationships the Centre has established across UQ.

Fortunately, Eric has agreed to retain a continuing appointment with the Centre ensuring the vision and his exceptional scientific capability is retained.

In terms of what we might do differently or in addition to the great work already in train, I see three key priorities for the Centre:

- Deepening our engagement with industry, particularly in the Asia-Pacific region
- Providing leadership at UQ in shaping our views on sustainability
- Helping to build the culture of innovation and entrepreneurship among the UQ engineering community

Finally, I would like to thank the Board of the Dow Centre and UQ's leadership for the confidence they showed in appointing me and I look forward to helping the team continue to deliver world class research outcomes in sustainable engineering innovation.



INNOVATION ACTIVITIES

2015

INNOVATION ACTIVITIES

We create environments and platforms to foster innovation and use a multi-disciplinary approach to develop technologies and their translation into practice

INNOVATION ACTIVITIES

THE PITCH PROGRAM

The Pitch Program, which successfully allocated funding to several projects in 2014 continued in 2015 with a budget of $300,000. The Centre is committed to maintaining the integrity of the original pitch program goals, which aim to support projects that are truly innovative with the potential for economically viable up-scaling. Specifically the program will support a member of the UQ community who seeks seed funding to develop an idea for an innovative technology that will contribute to sustainability. In 2015 many proposals sought financial support to assist in the commercialisation phase of a project, to fund additional or existing staff on continuing projects, or did not originate from the UQ community.

Two programs were selected to receive funding. Some received assistance in other ways.

» *Unravelling science, technology, engineering and mathematics (STEM) professionals' perspectives on nuclear energy*, A/Prof Maureen Hassal and Ms Peta Ashworth
Result: $100,000 approved to complete a survey, prepare a publication and use results to build a pitch for more funding or further research into the project.

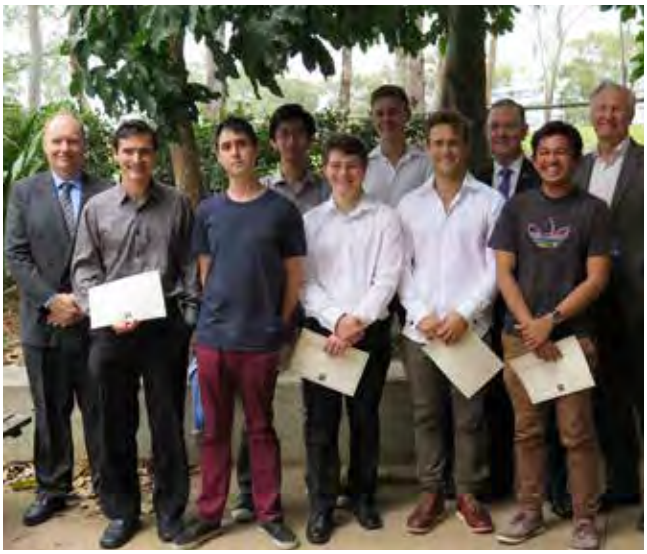
» *Large scale e-waste recycling: Is there really a problem?* Dr Glen Corder
Result: $15,000 approved to develop a joint publication.

» *Syngas to ethanol*, Dr Muxina Konarova
Result: No funding but Dow Centre will provide introduction with Haldor-Topsøe to arrange for testing of a new catalyst.

» *New Pelletising Technology for Improved Biomass Drying*, Mr John Webster
Result: Dow Centre examining platform.

» *3D printing of food*, Prof Bhesh Bhandari
Result: The Dow Centre evaluated options for a new project on "taking the farm out of food", but decided against it.

The continuation of the Pitch Program will come under review in 2016.



SISCA finalists and jury members

New Frontiers workshop at UCSB

Global Business Challenge awards night

Elevator Pitch

Witnessing a lack of mature venture capital in Australia, the Dow Centre attempted to remove a bottleneck in the development of promising environmentally sustainable innovations in Australia by facilitating access to international investment.

The Centre positioned itself to scout, screen and facilitate international investment for such innovations in support of global "Sustainable Prosperity". While American venture capital and corporate venture capital firms' interests were strong, there was an underwhelming response from Australian companies and potential innovators. In this light, further development of the program was stopped.

SISCA

This year's SISCA competition received excellent entries from the UQ student body. The winning team was TeeZee with a proposal for recyclable, easy to deploy attractive looking shelters. The $10,000 prize will help the team realise its goal of building a sustainable business. Runner-up was the Home^3 team, presenting its case for affordable, easy to construct, environmentally sustainable homes. The Dow Centre thanks all participants, the jury and everyone else who helped make this event a success.

UQ-UCSB

Following the success of the 2014 workshop "New Frontiers in Sustainable Fuels and Chemicals: What's beyond the horizon?", in February 2015 the Dow Centre and UCSB co-hosted the second edition of the New Frontiers workshop, which was titled: "2015, Terawatts, Teragrams, TeraLiters: Challenges and Opportunities for Sustainable Production of Chemicals and Fuels beyond the Shale Gale".

The 2015 workshop again attracted participants from academia, government and industry from several countries, among them UQ scientists, and a substantial delegation from China, sponsored by the University of Fudan. The organisation maintained a similar format to the 2014 workshop: several brief, provocative presentations, aimed at stimulating a lively discussion moderated by a panel.

A presentation on production of electricity and chemicals through the use of Thorium molten salt reactors attracted special attention by the audience, as this reactor can deal with most safety concerns that are currently limiting the deployment of nuclear technology.

The organising committee of the New Frontiers workshop was composed of: Eric McFarland (UQ), Craig Hawker (UCSB), Mike Doherty (UCSB), Charlie Campbell (University of Washington, Seattle), Chris Greig (UQ), Dongyuan Zhao (Fudan University).

Global Business Challenge

This year's Global Business Challenge (GBC) was to develop an innovative solution to aid the achievement of global food security through the doubling of food production by 2040. Exceptionally motivated trailblazing students from across the world entered for their chance to win a share of $225,000 AUD in cash and in-kind prizes. Fish 4 Africa from the University of Cape Town took out first prize, with their innovative aquaculture and fish processing design. Second Prize went to the Queensland University of Technology's Exatio, with a lemna (duckweed) high protein animal feed proposal. Third Prize was awarded to C-Fu from the Cornell University and Schulich School of Business, which presented a unique mealworm protein alternative to red meat. The Global Business Challenge topic of 2016 will be 'Health'.

INNOVATION - PROJECTS

MATERIALS

- Carbon fibre
- Novel uses of bromine in photochemical initiated chemical processes
- Novel routes to isocyanates and diphenyl carbonate using bromine

METHANE CONVERSION

- Thermochemical
- Biological

NUCLEAR

- Co-production of chemicals: improving the value proposition of nuclear power
- Advanced molten salt nuclear reactor designs
- Unravelling science, technology, engineering and mathematics (STEM) professionals' perspectives on nuclear energy

OTHER

- Uncovering the e-waste issue: current status and future opportunities
- Hazard sensing
- Mechano-chemical conversion
- PHA composite production from woody biomass
- Self-cleaning membranes for tallow recovery from abattoir wastewater
- The rapid switch project

Carbon fibre

Dr Bronwyn Laycock, Dr Pratheep Annamalai, Dr Jorja Cork, Dr Xiaoyu Wang and Mr Callum Hickey

The Dow Centre's carbon fibre research has been a core aspect of the Centre's contributions towards sustainable materials throughout 2015. This research primarily focuses upon finding a new and cost-effective pathway for the dehydrogenation of polymers and biopolymers for the production of carbon fibres using novel precursors. This program has been pursued through multiple parallel projects based on different polymer feedstocks, namely: polystyrene, polyethylene and nanocellulose fibres.

The Dow Centre, in partnership with the Dow Chemical Company (Dow), had a flagship carbon fibre research project in the conversion of polyethylene to carbon fibre. Currently the carbon fibre industry's largest cost base is in its polyacrylonitrile (PAN) feedstock. The Dow Centre's novel process for dehydrogenation may allow for a cheaper chemical precursor. In Q4 2015, the research team successfully produced intact carbon fibres with a solid core in high carbon yield, achieving the key original targets of this program. This challenging process required innovation in the initial low temperature stages of the process to prevent byproduct reactions that led to poor fibre properties.

A techno-economic analysis was conducted based on this lab data/process, projecting possible industrial behaviour. This analysis incorporated applicable commercial technologies with costing partially derived from advice provided by Deakin University. The resulting cost base for the production of carbon fibre was estimated at $6.85 USD per kilogram, a significant difference from the calculated $15.36 USD per kg for the PAN process at a 10 kta throughput. The process was based on 2013 feedstock figures and is for bulk PAN purchases of $5 per kg. A sensitivity analysis suggested polyolefins should be further investigated as alternative precursor via this processing pathway through detailed design and costings.

The project team visited Deakin University several times in 2015 to strengthen collaborations and plan scaled-up testing on the fibre lines. The research group at Deakin University and Carbon Nexus has been invaluable in providing industry insights and unit costing for the Centre's techno-economic modelling and the Dow Centre is very thankful for their collaboration.

The Dow Centre research into polyolefin precursors has been halted due to changes in the commercial interests in carbon fibre. At the end of 2015 the Centre was in negotiation with a potential new linkage partner for this ARC Linkage grant. Final summary reports have been prepared on the outcomes obtained to date and a review of the potential for joint intellectual property and/or publications from the work undertaken to date is underway. Follow up work finalising the model compound studies is in its last stages of preparation for an initial paper on this topic.

Research on carbon fibres from biomass on the remaining precursor studies, that were funded through an ARC Discovery grant, progresses in Professor Darren Martin's group at AIBN. Encouraging early results have been obtained on the effects of nanocellulose fibres from spinifex as additives for improving the PAN derived carbon fibre properties. There are some indications that other cheap feedstocks, such as polystyrene, can also be used in the production of lower-cost fibres.

Advanced applications of bromine based chemistry

Dr Yi Gu (leader project A), Dr Khuong Vuong (leader project B), Dr Reinhard Effenberger (ICL), Mr Brett Parkinson, Dr Simon Smart, Mrs Mojgan Tabatabaei Zavareh, A/Prof Craig Williams (UQSMBC) and Dr Yossi Zilberman (ICL)

In 2015 Bromine Compounds Limited (BCL) a Subsidiary of Israel Chemicals Limited (ICL) and The University of Queensland on behalf of the Dow Centre signed an agreement for the funding of two ICL fellows, which led to the following two projects:

A. Novel uses of bromine in photochemical initiated chemical processes

A cost-effective process that uses halogens to convert alkanes into olefins or higher value liquid products would have global significance. Such a process might eliminate the barriers to the use of natural gas and its high liquefaction and transportation costs when used for chemicals.

Unlike oxygen, using halogens as oxidants offers a unique means of performing partial oxidation of light alkanes to produce our most important chemical intermediates without ever producing carbon dioxide. It is likely that natural gas, and possibly methane hydrates, will provide ample supplies of light alkanes for chemical processing for decades to come. If these fossil resources are converted into polymers or other fixed carbon products (which are potentially recyclable) without producing carbon dioxide, then the net impact on the environment will be positive compared to current practices.

The major challenge for chemical science is to invent new efficient and cost-effective halogenation processes. A typical halogen-mediated alkane partial oxidation process consists of: i) halogenation of the alkane, ii) conversion of the alkyl halide intermediate to final products, iii) the separation of byproducts (such as polyhaloalkanes and hydrogen halide) and iv) halogen regeneration.

Among the halogens, bromine is preferred for C-H bond activation over other halogens (F, Cl and I) because the hydrogen abstraction with bromine and formation of HBr is a mildly exothermic free radical reaction. Bromide has acceptable selectivity for methane and mono methyl. In contrast, fluorination or chlorination reactions are highly exothermic and favour poly halogenated products, whilst iodination is endergonic. Moreover, the C-Br bond is weak enough to allow easier upgrade of alkyl bromides into olefins, alcohols, ethers and other high-value products.

This project aims to examine chemical pathways to significantly reduce process complexity and cost for C-H bond activation in alkanes and transformation to hydrocarbon products.

Outcomes to date are:

- Low temperature bromination of ethylbenzene followed by dehydrobromination, as a potential pathway to produce styrene.
- Reactive distillation of light alkanes, as a demonstration of process intensification for methane conversion.

B. Novel routes to isocyanates and diphenyl carbonate using bromine

Isocyanates and diphenyl carbonate are important building blocks for the syntheses of polyurethanes and polycarbonates, which have wide applications and huge market values $43B and $12B USD ($72.2B and $16.5B by 2020) respectively. Current production of isocyanates and polycarbonates, particularly isocyanates relies mainly on the use of phosgene. In addition to its very high toxicity and volatility, the production of chlorine is very energy intensive and is a significant cost contributor (up to 50%) to the production of phosgene. Dimethyl carbonate, DMC, has recently received significant attention as a benign solvent, fuel additive as well as a mild methylating reagent. DMC can also be used as an alternative to phosgene in the preparation of isocyanates and diphenyl carbonate. A more economically and environmentally sustainable method to prepare isocyanates and diphenyl carbonate would make a large and positive impact to the chemical industry.

The use of bromine instead of chlorine could potentially reduce the cost of producing polyurethanes and polycarbonates as bromine production and recycling from HBr is much less energy intensive when compared to chlorine. Overall this project aims to develop sustainable routes to isocyanates and diphenyl carbonate using bromine.

The project commenced in July 2015 and outcomes to date are:

- The in situ generation of bromo-phosgene ($COBr_2$) promoted by light or solid catalysts and its reaction with alkyl alcohol to generate dialkyl carbonate under mild conditions.
- One-pot production of dialkyl carbonates from CO, Br_2 and dialkyl alcohol with minimal formation of side-products using suitable solid catalysts.

This project will continue in 2016.

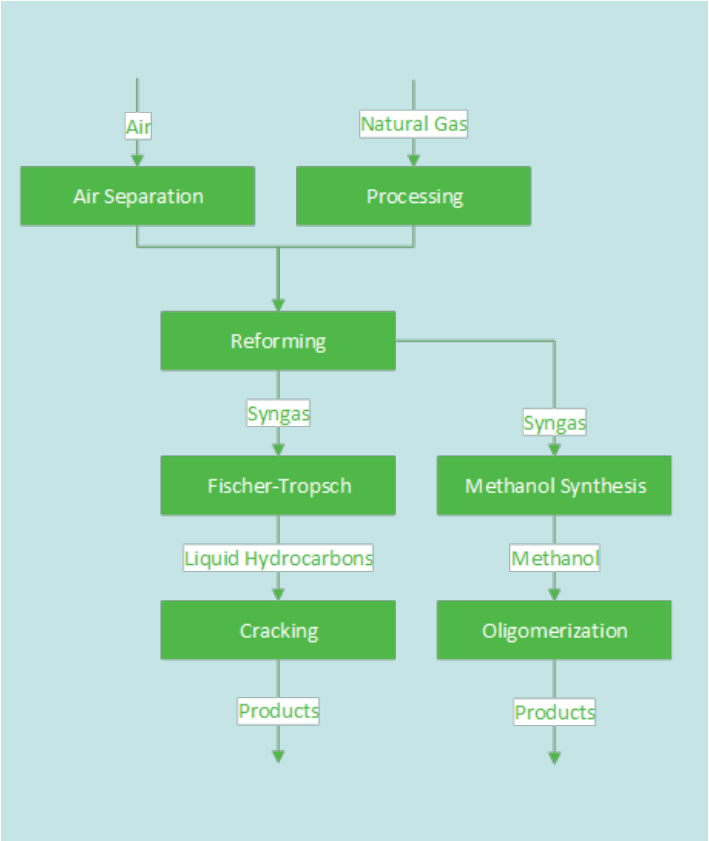
Methane conversion

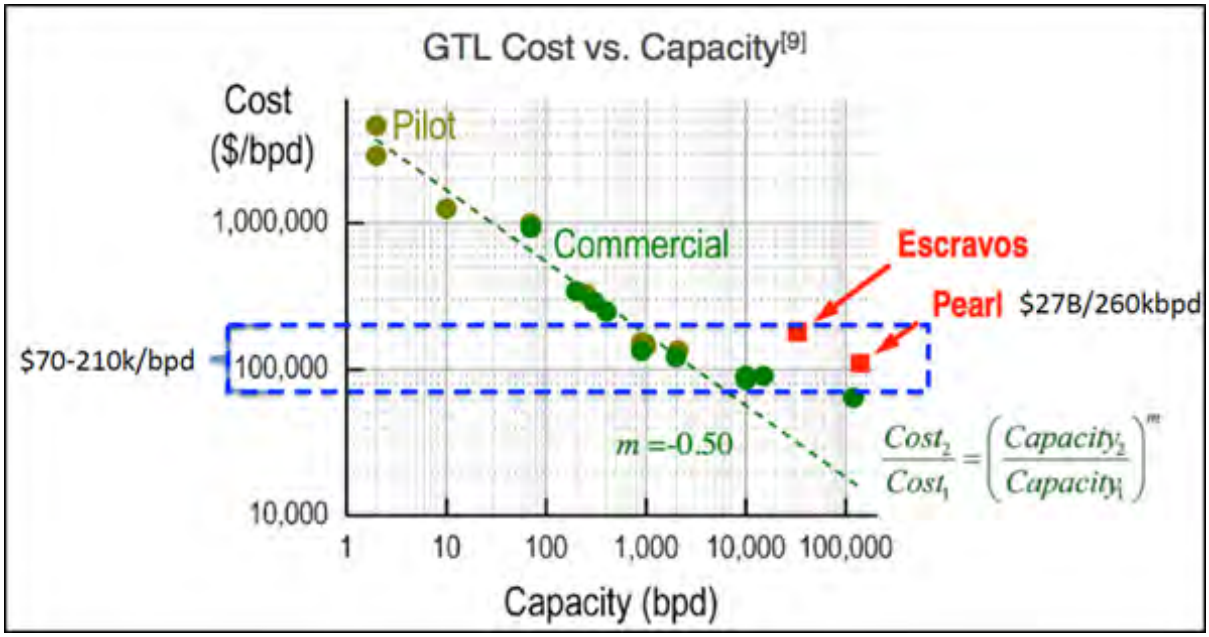
Mr Thomas McConnaughy, Mr Philip Grosso, Dr Jason Jooste, Dr Esteban Marcellin Saldana (UQAIBN) and Mrs Mojgan Tabatabaei Zavareh

Three methane-to-liquid conversion processes potentially suitable for small-scale applications were evaluated based on a 20 kta typical natural gas feed. None of the processes utilise synthesis gas as an intermediate. One process is based on biological methanotrophic pathways and the other two make use of halogens as oxidants, one with photochemical activation. Conceptual process models indicate opportunities for process simplification and intensification compared to conventional commercial processes. In all cases, the economics for small-scale conversion are challenging even with low cost methane becoming widely available.

Methane is an abundant and relatively low-cost hydrocarbon resource. Unfortunately, as a gas it is costly to transport and store, and as a stable molecule it has proven difficult to convert cost-effectively into more easily managed and valuable liquids. Presently, methane conversion to chemicals is limited to large-scale facilities supplied by gas from large reserves. The more abundant medium and small-size gas sources, including renewable biomethane, are underutilised; significant quantities are flared. New, cost-effective, processes that can make use of relatively small-scale gas sources would have a significant impact on the world's use of methane.

The base case results showed that small-scale utilisation of methane remains a difficult economic challenge. The solution may rely on the cheapest stranded gas remediation option (negative value). Cost reductions are possible through further process intensification and reduction of heat transfer and compression.



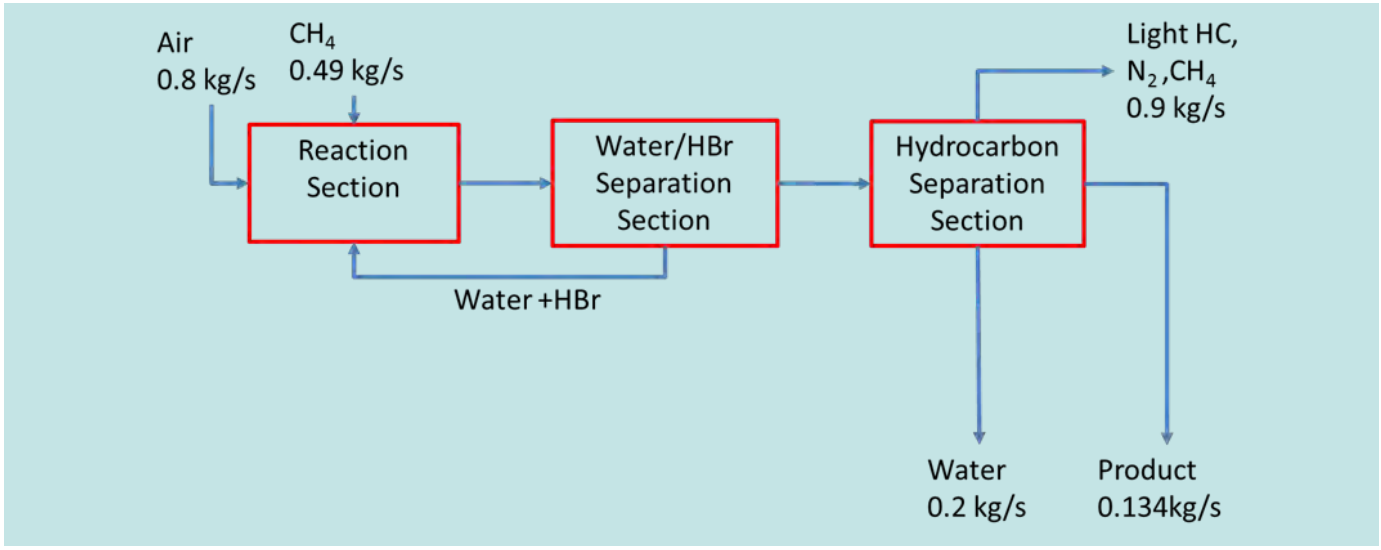


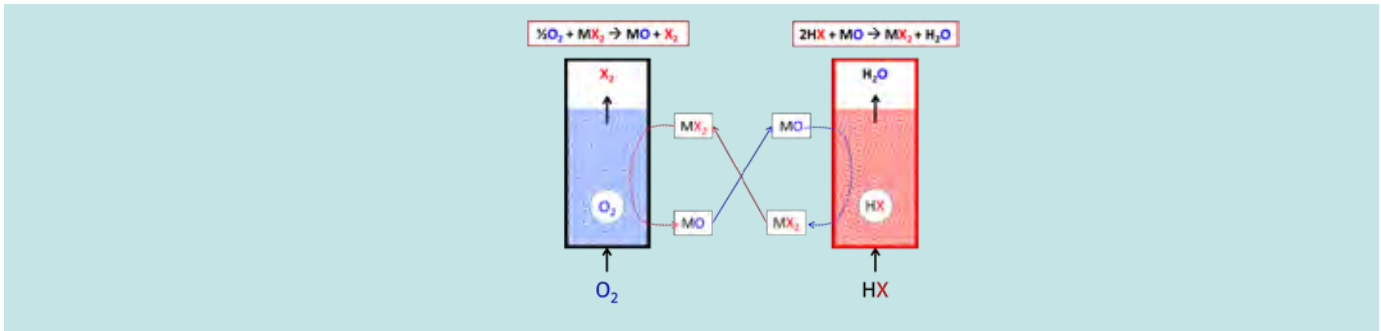
Thermochemical

Thermochemical methane conversion models typically suffer from expensive heat management equipment and therefore an important aspect in the design of this process was the incorporation of process intensification by maximising heat recovery and reducing unit operations. The process scheme for small-scale utilisation includes three main sections: reaction, quench/absorption and separation.

A product value of $750/MT for BTX and $550/MT for natural gas liquids (NGL) was used in the discounted cash flow analysis. The revenue is $7 million with a net profit of $1.9 million. This resulted in a return on investment of 2% and a payout time of 15 years. Further process refinement and intensification are required to reduce the cost of equipment to below a more attractive value of $3.5 million assuming similar costing factors. The cost of dealing with the heat exchange of hydrobromic acid is simply too expensive, due to materials of construction. Another method that does not require indirect heat exchange would likely reduce the evaporator cost and significantly affect the overall economics of this process. The outcome of the project led to investigating large-scale research. Small-scale utilisation with current technology is not viable.

The large-scale techno-economic analysis works to benefit from economies of scale while utilising molten salts in order to handle the heat management problem. Molten salts are used in the inorganic chemical and metallurgical industries, however, the application of these components in organic processes is limited to being used as a heat transfer agent. There are several advantages for employing molten salts in organic processes. The low vapour pressure of inorganic salts provides better gas and liquid separation, while the reaction rate and consequently product yield increases because of high operating temperatures. High heat capacity of molten salts assists to increase the heat recovery and heat management especially in the exothermic reaction processes. Furthermore, capturing the hydrogen halide through indirect oxidation by a metal oxide reduces the number of separation stages and minimises the amount of highly corrosive water/hydrogen halide solution in the process.



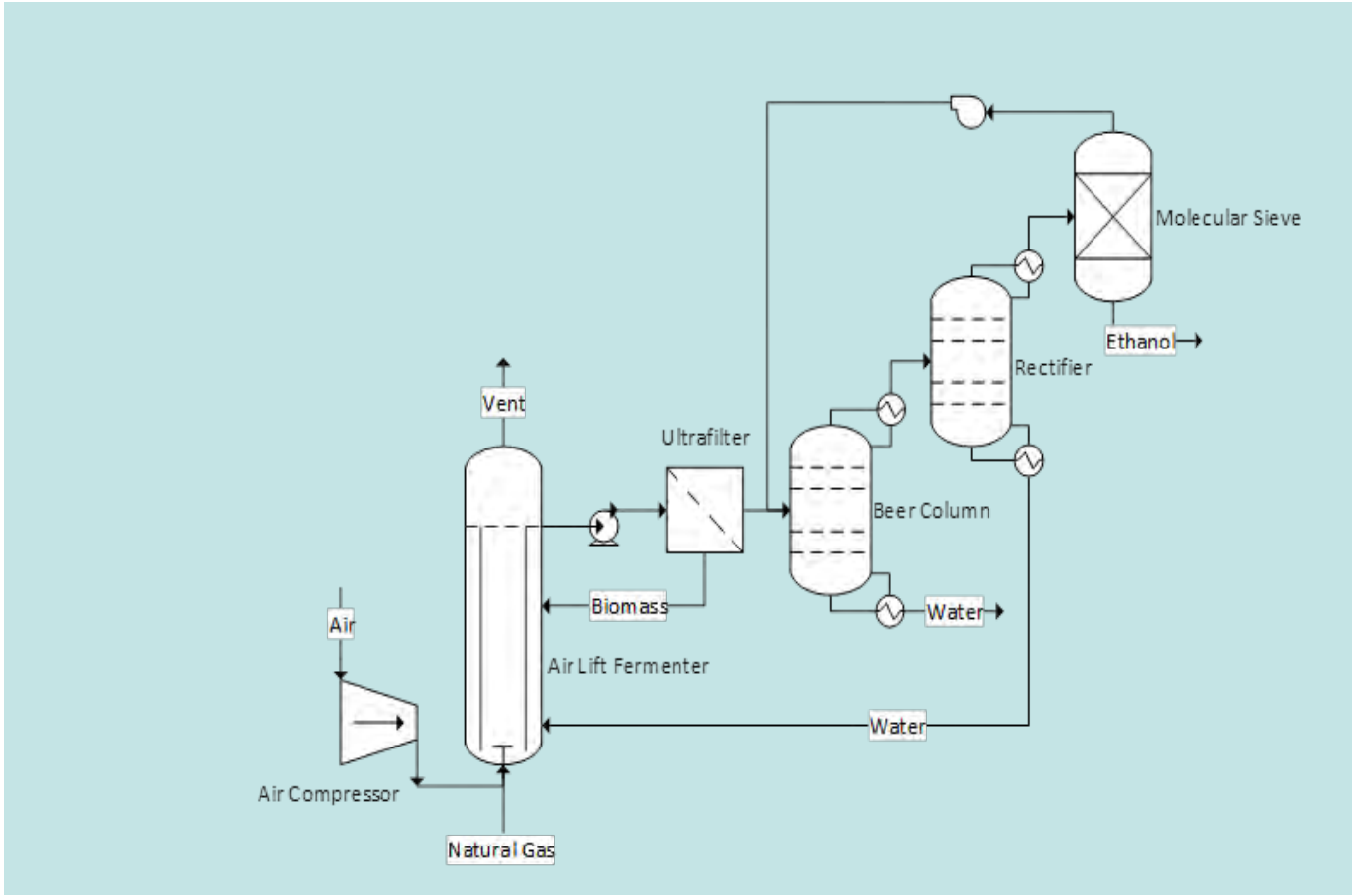


Biological

Biological methods of chemical production usually suffer from slow rate kinetics and large reactor volumes. In this model, methane is sparged into an advanced bubble column known as an air-lift reactor. During fermentation, many transport phenomena are active; however, either methane dissolution or cell uptake rate is assumed to be the rate limiting step for modelling purposes. An air-lift reactor was chosen for the process due to the capability of comparably high gas to liquid mass transfer rates to traditional bubble columns. Ethanol was chosen as an initial product for modelling purposes, however, higher value chemicals are the ultimate goal.

A discounted cash flow analysis was completed assuming a product value of $550/MT. The resulting revenue is $5.8 million per year with a net profit of $1.3 million per year. A calculated return on investment of 3% and payback time of 13 years leaves a difficult proposition for a FOAK plant design. A minimum sale price of $702/MT is required for an IRR of 10%. For an ethanol production plant, a competitive PCE would reasonably need to be less than $3 million assuming similar factors and contingencies.

While this particular application of methane fermentation (ethanol) is economically unattractive, the results warrant further investigation for potentially higher value products. Assuming no steep drop in production rate and yield, the production of chemicals such as acetic acid or 1,3-butenediol that have selling prices greater than $1/kg have potential to be of much greater interest and deserve further research. Furthermore, products that do not require an azeotrope separation that includes a molecular sieve should also be investigated.



The Dow Centre nuclear program

Generating large amounts of reliable and carbon free power is a pressing issue for our current society. Tough targets have been set by the international community and, with oil at the lowest price in a decade, decarbonising the economy is a seemingly impossible task.

Despite years of reliable carbon-free electricity generation, the nuclear power industry suffers from high capital costs, low public acceptance and lack of innovation in designing and constructing plants.

The Dow Centre nuclear program aims to understand these major constraints to wide deployment of nuclear power, promote thinking and create new ideas around old problems facing the nuclear power industry.

Improving the value proposition of nuclear power: Chemical co-production

Dr Diego Schmeda Lopez,
Mr Thomas McConnaughy and Mr Lucas Rush

Over decades of operation nuclear reactors have been proven to be a safe, reliable, large-scale carbon-free source of electricity. Despite a consistent safety record and the lack of carbon-free base load alternatives, few new nuclear plants are commissioned, while old plants are replaced with cheaper fossil-fueled alternatives. Nuclear power plants (NPP) produce relatively low-value electricity; their investment incentive and value proposition can be greatly enhanced by using the radiation generated in nuclear reactions for the co-production of valuable chemical products. In addition to providing significant additional revenue from a nuclear reactor, the use of radiation provides an opportunity for process intensification that makes possible the production of chemicals at a lower cost than from conventional processes without a significant impact on the capital cost of the reactor facility. Molten salt reactors (MSR) are particularly suitable for chemical co-production. Olefins are one possible class of important high-value chemical products that can be produced using gamma radiation.

The proposed process aims to use the energy available from the gamma rays emitted from the decay of gaseous fission products that are removed from the fuel salt of the MSR. These gases are removed from the salt and deposited in a charcoal bed that can be easily introduced to a chemical reactor to provide the necessary energy for a photochemical reaction. In this way a chemical plant can be effectively coupled to the nuclear power station. A potential advantage exists only if the use of radiation results in a far simpler and lower cost plant than the conventional technology.

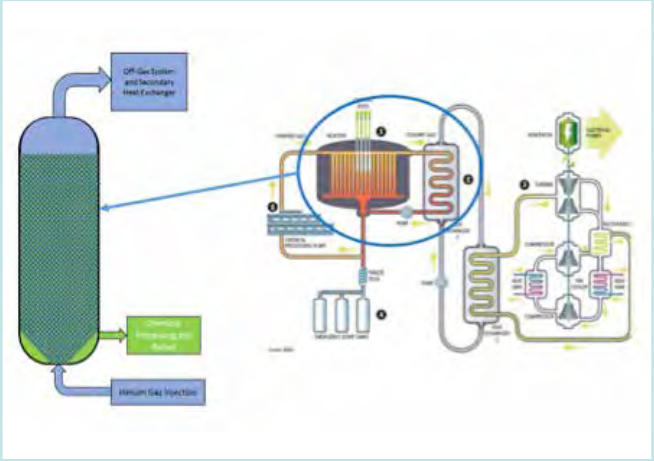
The estimated overnight cost for construction and start-up of a 1000 MW(e) NPP is approximately US$ 4.9B. The total energy generated for this plant is calculated to be 7,884 GWh per year, resulting in a net loss of just under US$0.9B per year. The overnight capital cost of a 500 kta styrene plant is US$380 million (~8% of the NPP mentioned before). This relatively small investment would increase the net revenue of the operating plant in over 71% to US$1,230 million per year. Despite this improvement, the investment is still not attractive due to the significantly large expense that the NPP involves. A bigger ratio between the capacity of the chemical plant and the NPP would benefit the financial viability of the project.

Advanced molten salt nuclear reactor designs

Mr Thomas McConnaughy, Mr Philip Grosso,
Dr Diego Schmeda Lopez and
Mr Samuel Shaner (MIT)

The most undeniable drawback to a wide deployment of nuclear power is the upfront capital that is required. Expensive control systems and redundancies in safety systems significantly increase the total cost of a nuclear reactor. These systems are necessary due to the intrinsic design characteristics of the conventional nuclear reactor.
Unlike conventional nuclear power, molten salt reactors are designed differently and the operational characteristics do not require many of the expensive features presented in light water reactors. Despite this, current core designs for molten salt reactors are still too complicated, often requiring expensive moderators manufactured in complex geometric shapes, which will be highly detrimental to the total cost of the project. In addition, the corrosive nature of the molten salt requires the use of expensive alloys that increases the cost of components such as heat exchangers.

The aim of this project is to propose simple core designs that permit the integration of multiple unit operations, and use direct heat exchange with the purpose of reducing the capital cost necessary to build and operate these reactors without any detriment to safety nor reliability.



Unravelling science, technology, engineering and mathematics (STEM) professionals' perspectives on nuclear energy

Ms Peta Ashworth, A/Prof Maureen Hassall, Ms Franziska Curran, Ms Philippa Dodshon, Dr Jill Harris and Dr Grace Muriuki

Nuclear power is a technology that polarises many across all levels of society – including technical professionals from across the science, technology, engineering and mathematics (STEM) disciplines. This research aimed to document STEM professionals' attitudes towards energy technologies and climate change, with a particular focus on nuclear power and to understand what influences those views. The project comprised a literature review and lexical analysis of publicly available information on nuclear power to compare who was writing on the topic (whether they were technical experts or not) and what they were saying. At the same time interviews (N=23) were conducted with influential scientists and technical specialists in Australia and internationally to understand their position in regard to energy technologies, climate change and particularly nuclear power. The information from these two work packages informed an on-line survey to elicit international STEM professional perspectives on nuclear power.

In total 250 surveys were completed comprised of 35 experts, 172 STEM professionals and 43 other non-STEM professionals. Responses were received from 23 different countries with the majority from Australia (52%), the UK (22%) and the USA (11%). The figure below shows how each group responded to the question "When you think of nuclear power, what first comes to mind?"

Although we are still conducting our analysis early correlation tests suggest that those with more positive views on nuclear energy today were more likely to support arguments for nuclear energy (.83); believe that positive consequences were more likely to result from nuclear energy (.65); and more likely to trust the nuclear industry (.69). They were less likely to believe that negative consequences will result from nuclear energy (-.66), or that a catastrophic event will result from nuclear energy (-.69). We have found that experts who have greater perceived and actual knowledge and more frequently seek out information about nuclear energy are also more likely to support its use – for safety, environmental and technical reasons. We recognise there are some limitations to the study particularly in relation to low numbers of experts and the other non-STEM group. Female representation was low and also the recruitment method for the survey was ad hoc. Ideally additional funds would be sourced to systematically target STEM departments across universities internationally as well as examine how attitudes change when engaged on the topic. Journal articles to report on the study are also underway.

Below are example quotes from each of the different groups that illustrate some of the responses when asked to describe what first comes to mind when thinking about nuclear power.

OTHER NON STEM

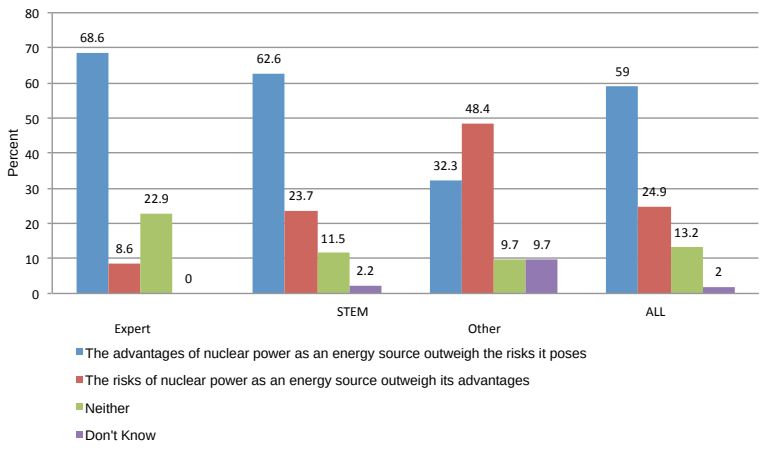
» I support nuclear power as it is more enviro friendly but am hesitant because of 1. The plant needs to be built strong enough to endure a catastrophe that we can't even imagine of yet and 2. Depends on what's going to happen to the waste.

STEM

» Nuclear risks outweigh benefits especially for future generations and considering the environmental and social risks.

EXPERT

» Nuclear fission needs strong regulation, but it is currently the most reliable, safe and long term electricity generator. Nuclear waste is an important issue, but there are no show-stoppers to safe and effective reprocessing of nuclear fuel or the safe disposal of high-level wastes from such processes.



Uncovering the e-waste issue: current status and future opportunities

Dr Diego Schmeda Lopez, Dr Simon Smart, Dr Glen Corder (UQSMI) and Dr Artem Golev (UQSMI)

Waste electrical and electronic equipment, WEEE or e-waste, has been considered as a problem for almost two decades. Due to the recognised value of material recovery, in some parts of the world, e-waste has been inappropriately processed causing serious environmental and human health issues. Efforts in tackling this issue have been limited and in many ways unsuccessful. The global rates for formal e-waste treatment are estimated to be below the 20% mark (Balde et al., 2015b), with the majority of end-of-life (EoL) electronic devices still ending up in landfills or processed in a rudimentary way. This paper critically overviews existing statistics and estimations for e-waste in Australia, including potential recovery value and environmental risks associated with metals recovery. First, existing production and market statistics for major valuable metals used in electrical and electronic equipment (EEE) is analysed and compared with current estimations of metal value in e-waste. Second, trade statistics for EEE in Australia over 1988-2014 are compiled and used for modelling EEE in-use stocks and e-waste generation over 2010-2014. Third, a deeper investigation into specific metals used in the electronic devices, their concentration and distribution between different components and types of devices is carried out. Following this, three basic scenarios have been applied to forecast EEE sales and e-waste generation in Australia over 2015-2024, including estimating the associated metal content and value. Finally, the results are used to analyse a range of existing and potential options for e-waste management, followed by recommendations to improve current practices and regulation.

Distributed sensors for hazard detection

Dr Diego Schmeda Lopez and Mr Callum Hickey

The project team designed a unique advanced, low-cost, wearable multisensor and also conceptualised a platform for data aggregation and analysis as a software system to monitor and relay a number of important chemical, biological and radiative hazards in real time for industrial chemical production companies.

The concept was proposed as a Software as a Service (SaaS) business designed to enable customers to have access to a real-time and site-wide profile of hazards, giving insight into their origin, direction and quantification. This information would be presented as a map overlay, agglomerating a multitude of data points and presenting the safety of a location in an easily understandable format.

The project formed a collaboration with CSIRO, which developed a prototype exclusively for the hazard multisensor for purposes of demonstration and engagement with industry companies.

Additional to the industrial chemical hazard sensing technology, a threat detection variation was constructed for the health industry. This project was concluded in Q4 2015, at the request of the Centre's Board and is currently in the process of being spun-out.

Mechano-chemical conversion

Mr Conor Young

The mechano-chemical research project investigated the technical feasibility of creating chemicals on the catalytic surfaces of freshly ground ore inside a ball mill. The ores of interest to the study were those which have high production volume and have been identified as potential catalysts in the literature, such as hematite (Fe_2O_3), ilmenite ($FeTiO_3$) and a nickel ore (NiS, NiO). Deformation and fracturing during grinding of these ores causes increased surface area and energy as well as localised high temperatures, which theoretically produce favourable conditions for reaction. The specific chemical pathway of interest was the partial oxidation of methane gas into syngas, with target chemicals of carbon monoxide and hydrogen gas to be produced. During the lab scale experiments, hydrogen was generated in both the experimental and control tests from an unidentified source.

PHA composite production from woody biomass

Mr Thomas McConnaughy, Dr Bronwyn Laycock and Dr Steven Pratt (UQ Chem Eng)

Biodegradable polymers are set to play an important role in the future of sustainable materials. Technical research has shown many positive mechanical properties of polyhydroxyalkanoates (PHA), therefore, the Dow Centre in collaboration with Steven Pratt and Bronwyn Laycock is developing a techno-economic analysis for the production of PHA composites from woody biomass. The project is funded by AnoxKaldnes - Veolia and Norske Skog. Currently, the cost of PHA production is too expensive to compete with conventional polyethylene. The focus of the TEA will be to determine if a PHA composite with wood fibre/flour can be produced at a competitive cost. Currently two innovative designs that are able to take biomass and convert it through fermentation to refined PHA mixed with wood fibre are analysed.

Outcomes to date are:

» Production schemes with a first order economic analysis

Results were presented to industry partners with the determination of further research in progress.

Self-cleaning membranes for tallow recovery from abattoir wastewater

Dr Simon Smart, Dr Benjamin Ballinger and Mr Callum Hickey

Abattoirs utilise large quantities of water for the cleaning and sterilisation of meat processing equipment. The wastewater collected from these operations may be purified on site through primary and secondary treatment with an optional tertiary treatment stage for water reuse.

Dissolved Air Flotation (DAF) units are traditionally used but they can be ineffective in their recovery of tallow. There is scope for a simple and cost effective alternative technology for increasing the production of salable liquid by-products in abattoirs. Membrane filtration technology has not been adopted by industry because of membrane fouling, which is the primary bottleneck to cost effective wastewater treatment and tallow recovery. Membrane fouling may lead to decreased treated water flow, over-designed capital, increased pumping energy and compromised integrity, which reduces its ability to separate and possibly recover valuable products. This further results in operational downtime and expense as the membranes must be aggressively cleaned, which can even reduce asset lifetime.

The Dow Centre conducts a small proof of concept benchscale pilot trial, funded by the Australian Meat Processing Council, to investigate the full scale benefits of membranes, which can be actively defouled in the red meat industry for tallow recovery. Work is currently underway to determine the operational performance of the membrane system and the next phase of the work will be to undertake a comparative technoeconomic analysis of the new membrane system against the traditional alternatives.

The rapid switch project: A global transition to a low carbon economy - limits of possibility?

Dr Simon Smart, Dr Joe Lane, Dr Diego Schmeda Lopez, Prof Andrew Garnett (UQSMI), Prof Chris Greig (UQEI), Prof Ove Hoegh-Guldberg (UQGCI) and Mr Callum Hickey

At the 21st Conference of the Parties in Paris (December, 2015) a global target to reduce emissions to 2°C above pre-industrial levels was announced with an additional emphasis on pursuing efforts to limit the temperature increase to 1.5°C. A massive transformation of the global energy economy is required if we are to make the deep reductions in the aggregate emission pathways consistent with this 2°C Scenario (2DS). However, the speed of this transition is poorly understood and often marginalised by policy makers, activists and technology experts/advocates alike.

The Rapid Switch project started in 2014 with the aim to examine the various stabilisation wedges that have been proposed to effect the decarbonisation transition for resource constraints, supply chains, manufacturing and organisational limits, constrains and bottlenecks to determine the maximum rate at which the world could realistically decarbonise the energy economy. Our hypothesis is that 2DS is no longer achievable and if this holds, we will determine what this means for atmospheric CO_2 concentrations.

The first publication from the project was released in 2015 looking at constraints in coal-fired power. Funding opportunities were limited for Rapid Switch in 2015 and so collaboration opportunities were pursued. These included the mentoring of student theses in collaboration with the School of Chemical Engineering on:

- *Assessment of energy efficiency potential in steel production* – this examined the technical potential and economic competitiveness of energy efficiency opportunities within the steel industry. The thesis found it highly improbable that energy efficiency can provide the required savings to realise a 2DS without even considering the timeframe for rollout.

- *Australia's future energy mix: considering the option to retrofit* - investigated whether retrofitting of coal power stations, rather than rebuilding, is a viable option for reducing carbon emissions. A real options analysis was conducted on a range of retrofit options in an Australian context. Retrofitting to gas was considered a better option than retrofitting to oxyfuel or rebuilding, although decommissioning gave the highest probability of the highest NPV.

Collaborators included the UQ Energy Initiative (UQEI), which is in the process of building a consortium with Princeton University and BP in the US, Tsinghua University and Rio Tinto in China and IIT Bombay in India. In 2016, Princeton Professor Robert Socolow visited UQ in a meeting hosted by the UQEI, an opportunity that was used to further Rapid Switch. Seed funding has subsequently been provided by the Centre and UQEI to further develop and test the methodology on a small case study. Outcomes will include a robust methodology that could be used across multiple wedges for multiple regions by our growing list of partners.

Journal publications

Klein-Marcuschamer, D.; Blanch H.W.: *Renewable fuels from biomass: technical hurdles and economic assessment of biological routes*. American Institute of Chemical Engineers AIChE J. 2015 Vol. 61, Issue 9., 2689-2714, John Wiley & Sons, doi: 10.1002/aic.14755.

Konda, N.V.S.N.M.; Singh, S.; Simmons, B.A.; Klein-Marcuschamer, D.: *An Investigation on the economic feasibility of macroalgae as a potential feedstock for biorefineries*. Bioenergy Research, 2015, Vol 8, Issue 3, 1046-1056, Springer, doi 10.1007/s12155-015-9594-1

Lane, J.L.; Smart, S.; Schmeda Lopez, D.; Hoegh-Guldberg, O.; Garnett A.; Greig, C.; McFarland, E.W.: *Understanding constraints to the transformation rate of global energy infrastructure*. Wiley Interdisciplinary Reviews: Energy and Environment, 2015, John Wiley & Sons, doi: 10.1002/wene.177

Mubeen, S.; Jun, Y.S.; Lee, J. and McFarland, E.W. *Solid Suspension Flow Batteries Using Earth Abundant Materials*. ACS Applied Materials & Interfaces, 2016, Vol 8, Issue 3, 1759-1765, doi 10.102/acsami.5b09515.

Singh, N; McFarland E.W.: *Levelized costs of energy and sensitivity analysis for the hydrogen—Bromine flow battery*. Journal of Power Sources, Elsevier, 2015, Vol 288, 187-198, Elsevier, doi: 10.1016/j.jpowsour.2015.04.114

Wang, Q.; Chen, H.J.; McFarland, E.; Wang, L.Z.: *Solar rechargeable batteries based on lead-organohalide electrolyte*. Advanced Energy Materials, 2015, Vol 5, Issue 24, doi 10.1002/aenm.201501418.

Public opinion

McFarland, E.M.: *Rethinking the U.S. Surrender on Nuclear Power*. The Wall Street Journal, April 27, 2015

Reports published on Dow Centre website

Klein-Marcuschamer, D.; Grosso, P.; Fong H.; McFarland, E.M.: *Techno-economic analysis of compression-based electric energy storage in natural gas pipelines*. 2015, http://www.dowcsei.uq.edu.au/filething/get/567/Techno-Economic%20Analysis%20of%20Energy%20Storage%20in%20NG%20Pipeline.pdf

McConnaughy, T.B.; Young, C.; McFarland E.M.; *Techno-economic evaluation of compressed air energy storage in unconventional applications*. 2015, http://www.dowcsei.uq.edu.au/filething/get/564/Techno-Economic%20Evaluation%20of%20Compressed%20Air%20Energy%20Storage%20in%20Unconventional%20Applications.pdf

Young, C. *Co-production of chemicals in mining by mechanochemistry*. 2015, http://www.dowcsei.uq.edu.au/filething/get/765/Mining%20Mechanochemistry.pdf

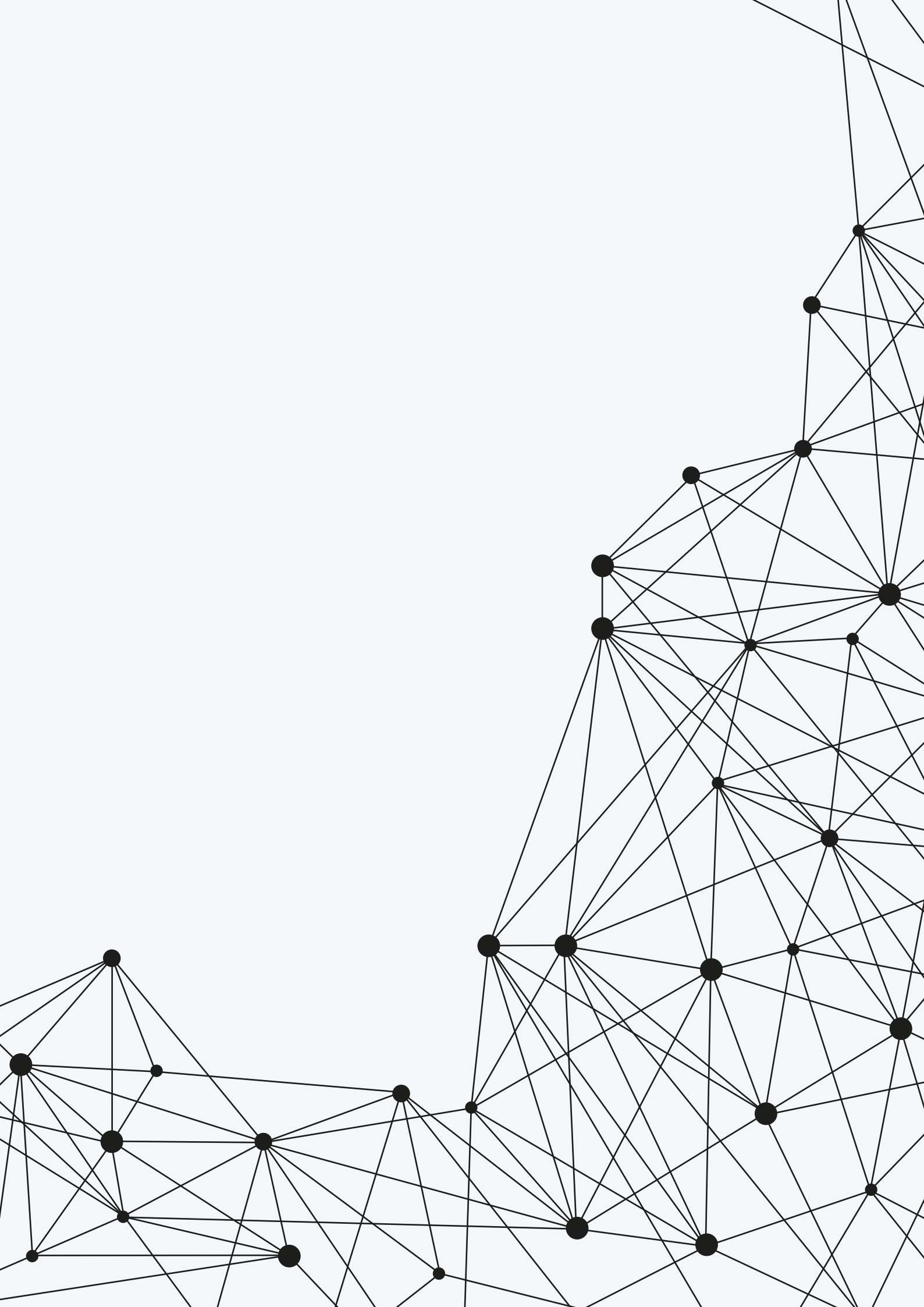
Confidential reports completed but not published

Hickey, C.; McFarland E.M.: *Techno-Economic analysis of carbon fibre from polyethylene*, 2015.

Schmeda Lopez, D.R.; McConnaughy, T.; Grosso P.; Fong, H.; McFarland, E.: *System cost analysis for chemical processing of lithium fluoride salt in a thorium fuelled nuclear reactor*, 2015.

Patents filed

McFarland, E.M.; Upham, D.C.; Metiu, H.; Gordon, M.; Jones, L.: *Chemical conversion using mixtures of different Halogens*. Application number 62188966, Filing date: 6 July 2015




EDUCATION
COMMUNICATION
COLLABORATION
2015

Dow Centre Fellowship Program

Throughout 2015, the Dow Centre has had the pleasure of welcoming three visiting scholars into its team: Ms Leila Safavi-Tehrani (UC Irvine), Mr Fadl Saadi (Caltech) and Mr Jamie Thompson (Loughborough).

Ms Leila Safavi-Tehrani

What did you do?

I did a techno-economic analysis on radioisotope production using the Szilard-Chalmers method.

What did you experience? What did you learn?

My experience at the Dow Centre was great, I learned so much from every single person at the Centre. Everyone was extremely friendly and always willing to assist. Professor McFarland, no matter how busy, was always available to offer help and guidance. He sparked my interest in various topics. I was fortunate to be able to attend Professor McFarland's lecture "The Science and Engineering of Energy Conversion" where I gained invaluable knowledge. It gave me a different perspective on some of the challenges we are facing regarding energy sources.

Which part of coming to Australia did you enjoy the most?

I really enjoyed my time in Brisbane, the weather was beautiful and I was able to enjoy outdoor activities such as hiking and bike riding. Also I really enjoyed working at the Dow Centre and being surrounded by amazing people.

Any suggestions for improvement?

Everything was great!

Mr Fadl Saadi

What did you do?

I performed some techno-economic analyses of different solar to chemical products and analysed their viability.

What did you experience? What did you learn?

I experienced an environment at the Dow Centre that was smart, hard working and intellectually curious. I feel like coming out of this experience, I have a much better ability to tackle seemingly open-ended questions in a methodical and organised fashion.

Which part of coming to Australia did you enjoy the most?

Getting the opportunity to meet new people, undertake new research and experience new ways about thinking about things.

Any suggestions for improvement?

It would have been nice to have a couple of other fellows start at roughly the same time I did, which would have helped me find people to experience Brisbane and Australia with.

Visiting student Leila with Mojgan Tabatabaei

Visiting student Fadl enjoying local highlights

UQ Sustainability Week Event

As in the previous year the Dow Centre contributed to UQ Sustainability Week with an event that was accessible to both UQ staff and students and the wider community. This year the Centre organised a poster competition: "Art Meets Science", in which participants could win $300 for a poster design that would capture "the ideas and challenges of sustainable technology".

The winning design came from Ms Jennifer McLeod, who works at the UQ Office of Marketing and Communications.

The University of Queensland / Mitsubishi Chemical Holdings / Asahi Kasei Corporation

In 2015 the Dow Centre coordinated and led a UQ delegation to two Japanese chemical companies: Mitsubishi Chemical Holdings and Asahi-Kasei Corporation. The purpose of these visits was to showcase UQ's world class research and commercialisation successes in Chemical Engineering, Materials Engineering, Nanotechnology, Biotechnology and Agriculture. The delegation, headed by UQ Pro-Vice-Chancellor Professor Anton Middelberg and Dow Centre Director Professor Eric McFarland and accompanied by Professor Darren Martin and Dr Simon Smart, addressed the Chief Technical Officer and numerous General Managers of Mitsubishi Chemical Holdings. A second smaller meeting with the Asahi-Kasei Corporation took place the following day.

The high level discussions revolved around six key research themes: Advanced Membranes, Sustainable Carbon Fibres, Sustainable Composites, Agricultural Chemicals, Sustainable Resources and Polymer Technology and involved researchers across the School of Chemical Engineering and the Australian Institute for Bioengineering and Nanotechnology. Joining via videoconferencing facilities in the Dow Centre at UQ, Dr Muxina Konarova, Dr Bronwyn Laycock, Professor Michael Monteiro and Professor Lars Nielsen were able to present their research work and interact with Mitsubishi researchers and managers. The presentations were all warmly received and numerous points of contact for individual collaborations were established. Communications with Mitsubishi Chemical Holdings and their subsidiaries are ongoing.

Movie Nights

For four nights, the Dow Centre break-out space was prepared as a cinema and the local community was invited to watch and discuss movies themed around sustainability. The four movies presented were:

- Switch, 31st March
- Cool It, 12th May
- An Inconvenient Truth, 17th August
- Merchants of Doubt, 20th October

Each movie was concluded with a discussion afterwards, where viewers were encouraged to share their viewpoints and perspectives on the topics raised. The movie nights were well attended by both UQ staff and students as well as members from the broader community.

Student Energy Network Launch Event

The Dow Centre is pleased to have hosted the Student Energy Network's 2015 launch event in first semester. The event familiarised the students with the Dow Centre and provided an opportunity for the Dow Centre to announce the launch of SISCA for 2015.

Flibe Energy

In February 2015 Dr Kirk Sorensen, Director of Flibe Energy visited the Dow Centre to kick off a collaborative project on molten salt thorium reactors.

The work with Flibe Energy delivered a preliminary design and cost for the blanket salt reprocessing system on their molten salt thorium reactor. The project included analysis of gamma ray activities for chemical production and had several thesis students involved. While Flibe did not receive the funding they had expected to support their work or the Centre's, the project has provided the Centre with demonstrated experience in nuclear engineering for potential future work with other parties. Results were presented at the September APCChE 2015 meeting and November AICHE meeting.

During his visit Dr Sorensen presented a well-attended seminar hosted by the UQ Energy Initiative, which was followed by a pizza night at the Dow Centre. The pizza night provided an informal opportunity to Dow Centre Team members to interact with senior EAIT staff and discuss energy issues with them.

Collaboration with the Brisbane Airport Corporation

In 2014 the Dow Centre signed a letter of intent-to-collaborate with the Brisbane Airport Corporation, due to their motivation to explore novel solutions to environmental sustainability challenges and their unique access to resources for applied research across a variety of disciplines. As reported previously under this collaboration a Chemical Engineering Intern assessed opportunities for reducing greenhouse gas emissions via operational changes at the Brisbane Airport. After her graduation the student was offered a position at BAC to further develop projects aimed at reducing emissions and resources, including the installation of ground power and pre-conditioned air for aircraft, feasibility studies on large-scale renewable energy and a study of the potential energy savings from modifications to the terminal doors. At the invitation of the Dow Centre she will also attend the 2016 edition of the New Frontiers Workshop in Santa Barbara as a member of the "Student & Recent Graduates" panel.

Representatives from the following organisations visited the Centre

- California Institute of Technology, Pasadena (CA), USA
- CSIRO, Pinjarra Hills (QLD) Australia
- The Dow Chemical Company, Zürich, Switzerland
- Flibe Energy, Huntsville (AL), USA
- Loughborough University, Leicestershire, UK
- Mitsubishi Corporation, Tokyo, Japan
- University of California, Irvine, (CA) USA
- University of California, Santa Barbara, (CA) USA

Centre members visited the following institutes/companies

Aachen University, Germany

AnoxKaldnes AB – Veolia Water Technologies, Lund, Sweden

Asahi Kasei Corporation, Tokyo, Japan

Christian Doppler Research Association, Vienna, Austria

Dalton Nuclear Institute, Manchester, UK

Deakin University, Geelong (VIC), Australia

Harnack House (Max Plank Gesellschaft), Berlin, Germany

Harvard University, Cambridge (MA), USA

Institute for Carbon Composites, Technische Universität München, Germany

Israel Chemicals Limited, Tel Aviv, Israel

Massachusetts Institute of Technology, Cambridge (MA), USA

Mitsubishi Corporation, Tokyo, Japan

National Nuclear Laboratory, Sellafield, UK

Norske Skog Paper, Boyer (TAS), Australia

Norske Skog Tasman, Kawerau, New Zealand

NuFarm Limited, Melbourne (VIC), Australia

Scion (Crown Research Institute), Rotorua, New Zealand

Technical University Darmstadt, Germany

Technion - Israel Institute of Technology, Haifa, Israel

Thales Underwater Systems, Sydney (NSW), Australia

The Dow Chemical Company, Midland (MI), USA

Transatomic Power, Cambridge (MA), USA

University of California, Santa Barbara (CA), USA

University of Sheffield, UK

University of Stuttgart, Germany

The Centre collaborated with three American universities in 2015

California Institute of Technology
Batteries

Massachusetts Institute of Technology
Low cost nuclear power

University of California, Santa Barbara
Carbon fibre and methane projects

The Centre partnered with seven organisations in 2015

AnoxKaldnes AB – Veolia Water Technologies
Report for PHA composite production from woody biomass

Australian Meat Processor Corporation LTD (AMPC)
Self-cleaning membranes

CSIRO - Pinjarra Hills
Hazard detection project

The Dow Chemical Company
Carbon fibre projects

Flibe Energy
TEA on thorium reactors

Israel Chemical Limited
ICL Fellows

Norske Skog
Report for PHA composite production from woody biomass

15
Special events and dinners attended

5
Round table/brainstorming events organised

3
Guest lectures given to undergraduate engineering courses

Other presentations by Centre members in 2015

Y. Gu	*A study of morphology control of porous carbons derived from microcrystal cellulose.* Talk. 9th International Mesostructured Materials Symposium, Brisbane, Australia
B. Laycock	*Novel approaches to carbon fibres: a two part story.* Talk. Carbon Fibre Future Directions Conference 2015, Geelong, Australia
B. Laycock	*Biomass utilization in biopolymer, nano-composite and carbon fiber production.* Talk. TUM-UQ Research Symposium, Technical University of Munich, Germany
B. Laycock	*Carbon fiber production from novel starting materials.* Talk. Technical University Darmstadt, Germany.
B. Laycock	*Biopolymer fundamentals and their importance in the global economy.* Talk. Industry Evening parallel to the PLSE 2015 conference, Brisbane, Australia
E. McFarland	*Zn-Br based flow batteries.* Invited Talk. 2015 Workshop on Advanced Materials for Energy Application, Australian Institute of Bioengineering and Nanotechnology, The University of Queensland, Brisbane, Australia
E. McFarland	UQ Innovation Mentoring Forum. Mentor. Research Partnerships Office, The University of Queensland, Brisbane, Australia
E. McFarland	*Discussion on energy issues.* Invited Participant. Future Agenda Workshop, Global Change Institute, The University of Queensland, Brisbane, Australia
E. McFarland	*The chemical industry in the next industrial revolution, the "Sustainable One".* Panel Member. Rio Tinto/EPIA Energy Exchange Series Breakfasts, Brisbane, Australia
E. McFarland	*Creating a compelling nuclear value proposition through co-production.* Invited talk. Presented at the University of Sheffield, the National Nuclear Laboratory, Sellafield and the Dalton Nuclear Institute, Manchester, UK
E. McFarland	*Oxyhalogenation: Light alkane conversion without carbon dioxide.* Invited talk. Catalysis Conference, Telluride, USA
E. McFarland	*Coproduction of chemicals: Improving the value proposition for nuclear power.* Invited talk. AICHE, Salt Lake City, Utah, USA
E. McFarland	*From out of the box to way out of the box: Understanding catalytic processes for sustainable prosperity.* Invited talk. Harnack Haber-House, Berlin, Germany
E. McFarland	*Industry-university collaborations and the Dow Centre.* Talk. Research Showcase: Engaging with Rural Industries, Institute for Future Environments, Queensland University of Technology, Brisbane, Australia
D. Schmeda Lopez, M. Tabatabaei, T. McConnaughy	*Advanced methane conversion technologies: Beyond synthesis gas.* Poster. Asian Pacific community of chemical and process engineers and industrial chemists conference (APCChE 2015), Melbourne, Australia
S. Smart	Discussions on water, food and energy, Future Agenda Workshop. Invited participant Global Change Institute, The University of Queensland, Brisbane, Australia
X. Wang	*Exploration of irradiation and catalysis to facilitate dehydrogenation and carbonisation of polyethylene.* Guest Presentation. The Dow Chemical Company, Midland, Michigan, USA.

INTERVIEW WITH INCOMING DIRECTOR CHRIS GREIG

Professor Chris Greig commenced his role as Centre Director at the beginning of 2016

Professor Chris Greig
Director, Dow Centre for Sustainable Engineering Innovation
Director, UQ Energy Initiative

- Born in Townsville, Australia
- Chemical Engineer with BE & PhD from UQ
- Fellow of the Academy of Technological Sciences & Engineering
- Founder and MD of STG - a sugar technology start-up business from 1986 until successful exit by sale in 1999
- 12 years' senior executive experience in construction & energy resources sector
- Joined UQ as Professor of Energy Strategy and Director of the UQ Energy Initiative in late 2011
- Non-Executive Director roles have included ASX listed engineering and construction companies as well as Deputy Chairman of Gladstone Ports Corporation

INTERVIEW WITH INCOMING DIRECTOR CHRIS GREIG

From 2016 Prof Greig will join the Dow Centre as its new Director. Taking up the leadership from inaugural Director Prof McFarland, he will lead the Dow Centre in its next phase, with a focus on leveraging the Centre's unique capabilities and early successes to drive engineering innovation and increase impact in the Asia-Pacific region.

Prof Greig is no stranger to innovation having founded a successful sugar technology company during his PhD studies which he ran as MD for 13 years before exiting in the late nineties. Prior to joining UQ to establish the UQ Energy Initiative, Prof Greig was also Project Director and CEO of ZeroGen, which conducted one of the world's most comprehensive and pioneering studies on the potential of a large scale, low emissions coal fired power project incorporating carbon capture and storage.

What do you see as the most exciting opportunities and/or challenges for the Dow Centre in the next 12 months?

One of the biggest opportunities and challenges for the Dow Centre in the coming year arises from the volatility in the markets for many key industries globally and particularly in our region.

The other really interesting development came in Paris, at the 21st Conference of the Parties to the UNFCCC, which delivered what has been widely hailed as an historic agreement to limit climate change. For the first time we saw the world commit to 'hold the increase in the global average temperature to well below 2°C above pre-industrial levels and to pursue efforts to limit the increase to 1.5°C'.

The Paris gatherings also saw 20 countries including Australia sign on to Mission Innovation, an initiative that aims to double investment in clean energy innovation over five years. Of course such clean energy innovation will need to diffuse through the entire economy.

Never before has the need to invest in research and innovation been greater as we embark on a low-carbon transformation of the economy in a time when industry confronts tremendous volatility and uncertainty.

As the new Director of the Dow Centre, what will be your key focus areas for 2016/2017?

The Dow Centre will continue the good work of its two start-up years to pursue innovation around sustainability issues that are industry relevant and engineering related. Areas where we might refine our focus include:

- Adopting a more regional focus targeting the Australia-Asia-Pacific region
- Expanding and deepening our engagement with Industry
- Seeking to influence government policy in relation to sustainability issues affecting our industries
- Extending our sponsorship of innovation and entrepreneurship among UQ students and academics

In Australia, business investment into research (and therefore also innovation) is lower than many other OECD countries. How do you think links between research/universities and business can be improved?

You highlight a critical issue for Australia's competitiveness that will not be helped in the near term by the market volatility and uncertainty facing business. Addressing the world's big sustainability challenges requires transformational change in the economy that will demand significant innovation for which technology will be a vital thread.

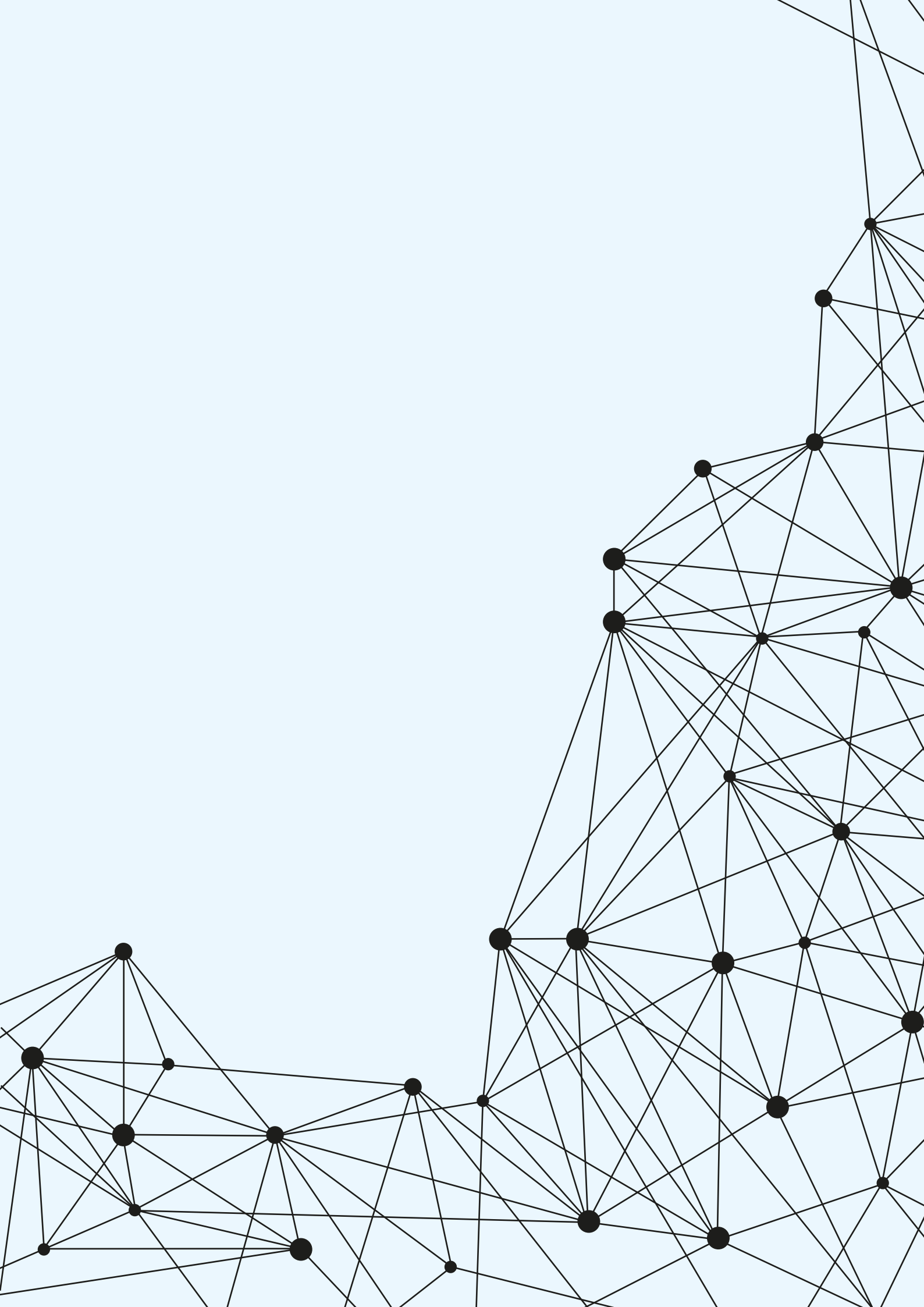
The kind of innovative culture we need however, is typically characterised by patient, long-term investment and often a high level of failure. Australian business on the other hand, has traditionally been risk-averse, and so if we are to evolve a more innovative culture Australia needs to de-risk investment in research and innovation. This will accelerate public and private sector collaboration and it will facilitate more and deeper University-Industry linkages.

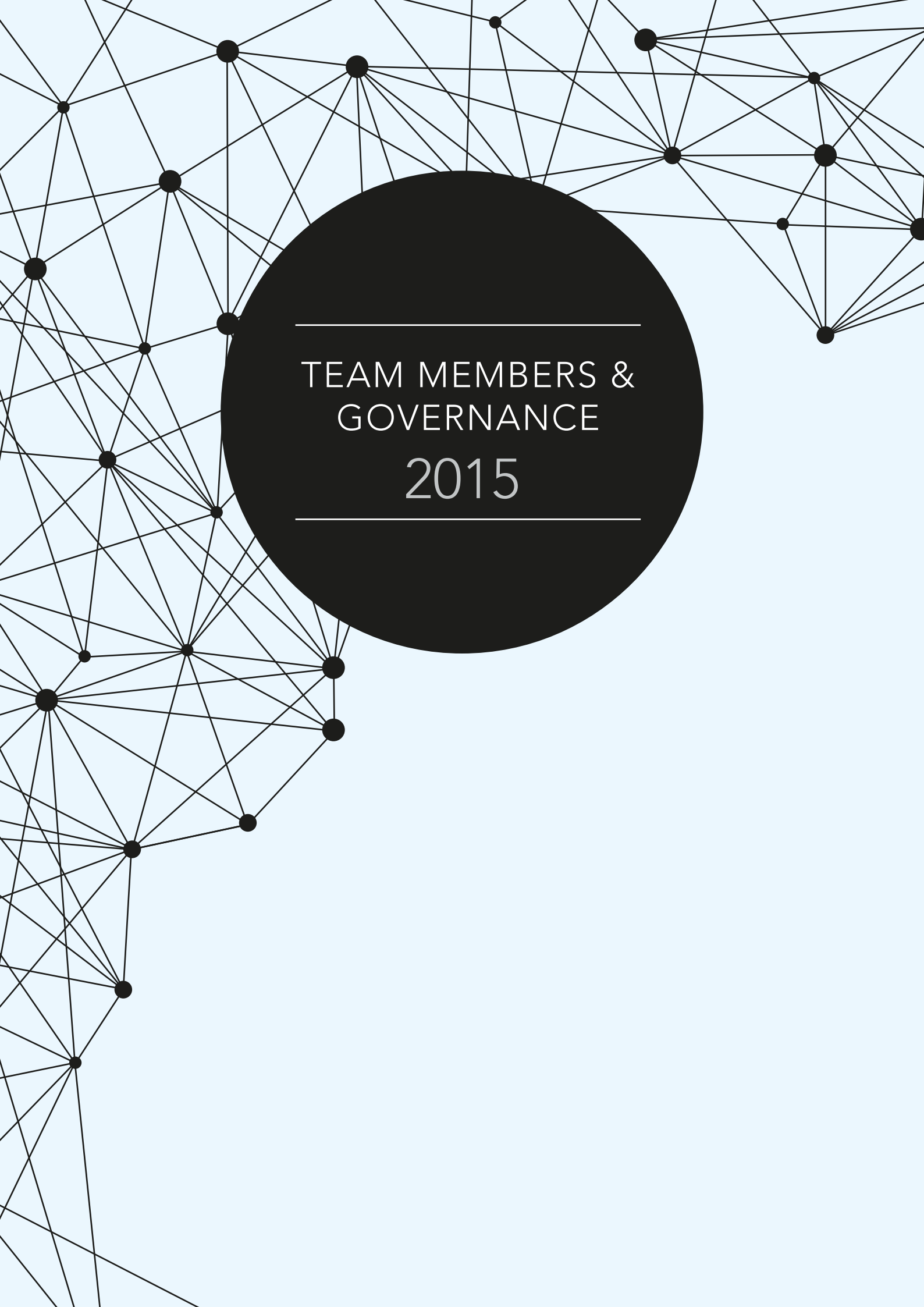
At the same time Universities must work harder to engage deeply with industry to understand their challenges and to have their valuable guidance on industry challenges and research needs.

Do you think the recently announced (by the Australian Federal Government) 'National Innovation and Science Agenda' will boost innovation? Can the Dow Centre be part of this 'ideas boom'?

The basic premises behind the National Innovation and Science Agenda are surely taking us in the right direction. Implementation will be critical as always.

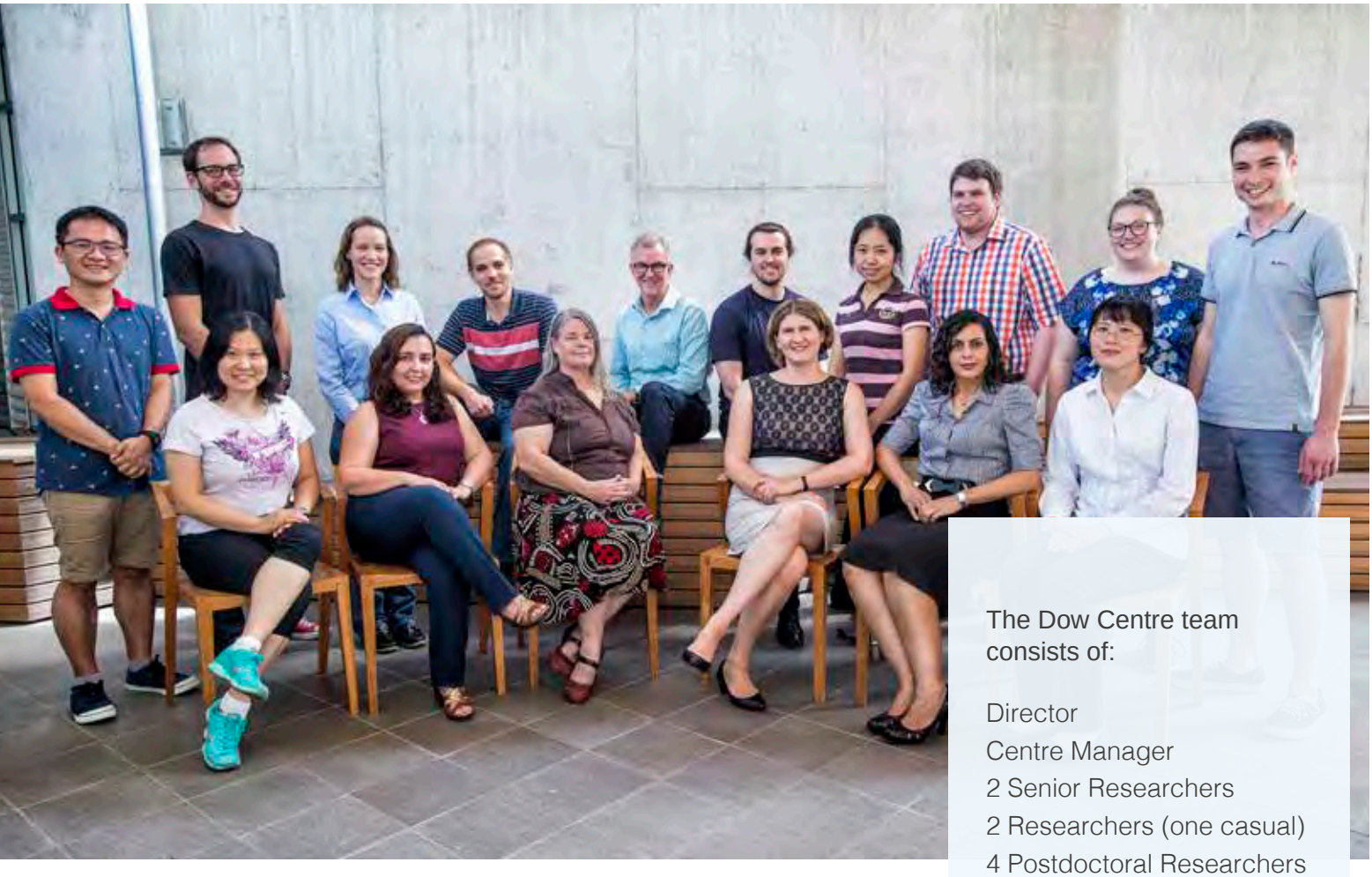
The Dow Centre is ideally positioned to be a part of this so-called ideas boom. We are focused very much on ideas that can 'move the needle' in terms of more sustainable production and use of energy, water, food and materials. These are the legacy industries upon which economies are founded. Our approach to focus on not just technological innovation but through a transdisciplinary socio-techno-economic assessment lens, makes the Dow Centre quite unique among research universities. It's the lens that screens the many great 'ideas' to select those the have significant 'real world' impact.





TEAM MEMBERS & GOVERNANCE 2015

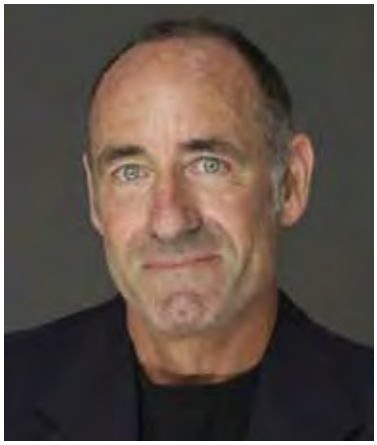
THE TEAM



The Dow Centre team consists of:

Director
Centre Manager
2 Senior Researchers
2 Researchers (one casual)
4 Postdoctoral Researchers
4 Analysts
2 Research Assistants (Casual)
3 Consultants
2 RHD Students

THE TEAM



Prof Eric McFarland
Director until 31 Dec 2015

Eric studied nuclear engineering at the University of California, Berkeley and the Massachusetts Institute of Technology (MIT) where he received his PhD and later joined the Nuclear Engineering Department faculty. He has an international reputation for his research, which over the last ten years has been in catalysis and fundamental chemical science related to energy and chemical conversions.

In 1991, 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 to become the inaugural Director of UQ's Dow Centre for Sustainable Engineering Innovation, 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. He has also studied medicine and received his M.D. from Harvard Medical School and practiced emergency medicine part-time until 2005; he has continued to serve as a volunteer physician for several relief agencies. In January 2016, Eric returned to the University of California, Santa Barbara where he will retain collaborative projects with UQ and the Dow Centre.

As outgoing Director, I am excited to have been given the opportunity to remain active in the Centre's technical programs and continue to work with the exceptional Centre team.

Prof Lars Nielsen
Deputy Director until 31 Dec 2015

Lars heads the Systems and Synthetic Biology Group at the Australian Institute for Bioengineering and Nanotechnology (AIBN). Using thermodynamic principles, novel approaches are developed for the rational design of complex pathways as well as handling complex, transient dynamics in developing tissue. A team of 50 people use these novel approaches in the design of bioprocesses as diverse as the production of blood cells for transfusion and the production of industrial biopolymers.

Lars has contributed extensively to genome scale modelling, developing the first models for animals and plants and the first multi-tissue model to describe C4 metabolism. Much of his group's work is focussed on integrating flux analysis with comprehensive omics analysis (genomics, proteomics, metabolomics) and he heads the Queensland Node of Metabolomics Australia.

Lars was part of the team that devised the concept plan that led to the UQ-Dow Donation agreement in 2012 and the birth of the Dow Centre.

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.

It is a joy to work in an energetic environment with motivated and friendly team members!

THE TEAM

Dr Howard Fong
Senior Consultant (part time)

Howard received his Bachelor of Science in Chemical Engineering from San Jose State University and PhD in Chemical Engineering from the University of California, Berkeley. He joined Shell Development Company (Shell Oil Company) at the then Westhollow Research Center in Houston, Texas, in 1975, and rose to the rank of Managing Engineer, the highest technical rank of the Royal Dutch Shell Group. He retired from Shell in April of 2010. 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. Since retirement, 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.

I am excited to consult for the Dow Centre because it shares my philosophy that no technology development is truly sustainable unless it is also economically viable and competitive.

Mr Philip Grosso
Senior Consultant (part time)

Phil contributes to the Dow Centre by providing analysis of the economic and technical feasibility of chemical and other processes and also in the development of new and novel processes. Phil has over 55 years of experience in chemicals, minerals and metals industries. He has held positions at DuPont, Kaiser Aluminum & Chemical and Engelhard Corporation. His responsibilities ranged from process design, project management, engineering management, plant operations, marketing, to full management of the Diversified Chemicals group of Kaiser Chemicals as V.P. & General Manager. He has had extensive experience in a wide range of inorganic and organic chemicals and also with aluminum, magnesium and titanium metals. He also served as Vice President & General Manager of the Crystal & Electronic Products Division of Kaiser (later Engelhard). For over twenty years to the present he has served as a self-employed consultant. He holds a Bachelor of Chemical Engineering degree and a Certificate of Advanced Engineering Study (Masters Equivalent) from Cornell University. He is registered in California as a professional engineer in chemical and manufacturing engineering.

The Dow Centre mission matches and makes use of my decades of experience and accumulated knowledge and skills.

Dr Daniel Klein-Marcuschamer
Consultant (part time until July 2015)

Daniel is currently an independent consultant for projects in renewable energy and chemical production. Until July 2015, he was a consultant for the Dow Centre providing expertise in techno-economic analysis of chemical processes. Previously, Daniel was the Senior Analyst at the Dow Center, the Director of Techno-economic Analysis at the Joint Bioenergy Institute (JBEI) and Project Scientist at Lawrence Berkeley National Laboratory (Berkeley Lab). In recognition of his successes, Daniel was the 2012 recipient of the Berkeley Lab Early Career Award for Exceptional Achievement and the 2012 JBEI Technical Contribution Award. Daniel is the author of seven patents, among them four currently licensed and has authored numerous peer-reviewed publications in the field. His work has been highlighted by The Economist, Science Magazine, Biofuels Digest, Science Daily, The Age, The Sydney Morning Herald and The Australian, among others. He has lectured at the Massachusetts Institute of Technology and at the University of California, Berkeley.

Daniel graduated Summa Cum Laude with a B.S. in Chemical Engineering from the University of Texas at Austin and holds a PhD in Chemical Engineering from the Massachusetts Institute of Technology.

THE TEAM

Dr Bronwyn Laycock
Senior Researcher (part time)

Bronwyn has a diverse background in translational research - degradable polymers, biomaterials, organic and organometallic synthesis, pulp and paper chemistry and general polymer chemistry. As a Project Leader and Deputy Program Leader within the CRC for Polymers, she managed a project that delivered an oxodegradable thin film polyethylene that was commercially licenced by Integrated Packaging. This work earned the team a Joint Chairman's Award for research/commercialisation (CRC for Polymers). A former Senior Research Scientist (CSIRO Division of Molecular Science), she was awarded the Joint CSIRO Medal for Research Achievement 2009 for her work on the extended wear contact lens project (within the Vision CRC), which was successfully commercialised by Ciba Vision as the Focus Day/Night and the O2Optix lenses – these now being 50% of the contact lens market. In the Dow Centre Bronwyn is the leader of the Carbon Fibre project.

I feel privileged to be working for the Centre and in sustainable engineering. It means that I work with passionate, deeply knowledgeable and committed researchers dedicated to ensuring that our efforts will make a genuine and significant improvement to global sustainability.

Dr Simon Smart
Senior Researcher (part time)

Simon is a Senior Research Fellow in the Dow Centre for Sustainable Engineering Innovation and a Senior Lecturer in the School of Chemical Engineering at The University of Queensland. In the Dow Centre Simon has been involved in the Rapid Switch project, which examines the various climate stabilisation wedges that have been proposed to effect the transition towards a low carbon future. Other research foci include developing enabling technologies for clean energy and water applications. This work involves the design and development of inorganic and hybrid nanocomposite materials for membranes and membrane reactors. In conjunction with UQ's Functional Interfacial Materials and Membranes Laboratory (FIM2Lab) where he is deputy-director, Simon is pursuing a range of novel membranes including Self-Cleaning Membranes and Flexible Ceramics. He currently holds a Queensland Government Smart Futures Fellowship (ECR) for his work into membrane distillation of coal seam gas waters. Simon has 62 publications including 8 book chapters and 54 international peer-reviewed journal articles.

Finally a chance to use my engineering skills on real world problems!

Dr Joe Lane
Researcher

Joe is a Research Fellow, with a professional background spanning process engineering, water resource planning and environmental management. His past research has focused on the science of sustainability assessment, putting priority on bridging the gap between methodological robustness and practicality for decision makers. Much of that work used the Life Cycle Assessment (LCA) methodology – analysing applied case studies in the urban water industry, but with a strong focus on developing improved datasets and impact assessment models for this task. Prior to joining the Dow Centre, Joe also lead the UQ contribution to the development of the Australian Industrial Ecology Virtual Laboratory – a collaboration between nine different Australian research groups, developing innovative tools for coupled environmental-economic analysis. Joe has contributed to the Rapid Switch project, compiling preliminary analysis of global energy system forecasts. Joe also managed the Dow Centre interactions with the Brisbane Airport Corporation and has been reviewing opportunities for solutions to sustainability challenges associated with water and plant nutrients management. As a part of the latter, Joe has assisted the startup of a multidisciplinary UQ research initiative into novel fertiliser products and processes.

The focus of the Centre - introducing real-world feasibility assessment into technical research and introducing technical practicalities into environmental debates – offers a fantastic opportunity to be involved in research that might overcome some of the inertia that holds back solutions to sustainability challenges.

THE TEAM

Dr Khuong Vuong
Researcher (from July 2015)

Khuong started working at the Dow Centre as a research fellow in July 2015. He obtained his BSc (Chemistry and Biochemistry) from the University of Sydney, Australia. His PhD and BSc (Honours) are from the University of New South Wales, UNSW, Australia in the area of organometallic chemistry and catalysis. After graduating, he worked as a researcher at the University of Nottingham, UNSW and the Institute of Chemical and Engineering Sciences, A*STAR-ICES, Singapore prior to joining the Dow Centre. He has worked in a number of successful collaborative projects and has good experience in synthetic chemistry, catalysis, photochemistry and biomass conversion. He has co-authored more than 25 journal papers. Khuong is interested in developing environmentally and economically sustainable chemical processes.

Bromine Rules!

Dr Jorja Cork
Postdoctoral researcher (part time)

Jorja received her PhD in Materials Chemistry at The University of Queensland (UQ) in 2015 focusing on the development of elastic and degradable polymers for use as artificial vascular grafts. She has worked as a Post-Doctoral Research Fellow at the Australian Institute for Bioengineering and Nanotechnology (AIBN) testing the barrier properties of thin starch-based biopolymer films for the packaging industry in conjunction with Plantic in Melbourne, Victoria. She also worked for the Collaborative Research Council (CRC) for Polymers at Queensland University of Technology (QUT) testing the quality and monitoring the degradation of ultra-thin biopolymer films used to improve high-value crop propagation for the Victorian-based company Integrated Packaging. Since joining the Carbon Fibre team at the Dow Centre in March 2015, Jorja worked closely with Dr Xiaoyu Wang towards developing novel processes for low-cost, high-efficiency carbon fibre production from polyethylene precursor to meet automotive and industrial performance specifications.

I love working as part of a highly motivated team at the Dow Centre in which small-scale experimental data is combined with techno-economic analysis models to quickly identify efficient pathways toward the economically sustainable innovative products of tomorrow.

Dr Yi Gu
Postdoctoral researcher (from May 2015)

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

The Dow Centre is a lovely place to work. It encourages new ideas and provides great opportunities.

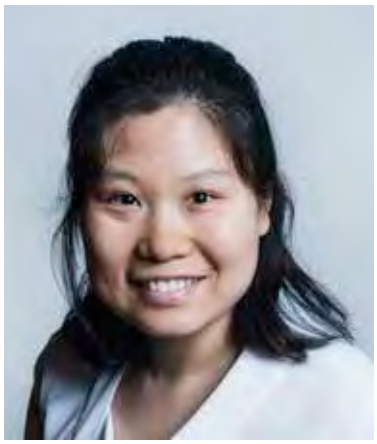
THE TEAM

Dr Diego Schmeda Lopez
Postdoctoral researcher

Diego joined the Dow Centre in 2015, under the Rapid Switch Project.

He received his Bachelor and Master of Science in Mechanical Engineering from the Federal University of Rio Grande do Sul, in Porto Alegre, Brazil in the years of 2007 and 2010 respectively; He was awarded his PhD in Chemical Engineering from The University of Queensland in 2014. Before entering The University of Queensland, Diego worked as project and process engineer in the plastic industry and in the steel industry, 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 Masters he worked on the topic of energy generation, sustainable use of energy and energy efficiency. During his PhD, he researched the development of industry friendly metallic materials for membrane applications and developed stainless steel hollow fibres.

Diego is now the project leader in the Dow Centre nuclear program and an active participant in the Rapid Switch project.



Dr Xiaoyu Wang
Postdoctoral researcher

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

Mr Callum Hickey
Analyst (from February 2015)

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

During 2015, Callum's projects included contributing towards a long-life low-fouling membrane design, the intensification of food production and establishing a video-based venture capital pitching network. He also significantly provided input into the low-cost production of carbon fiber and hazard detection network projects.

Callum continues studying a Masters of Business at UQ.

I enjoy working in challenging projects.

Closely cooperating with industry is very inspiring for my research work in the Dow Centre.

The most important question I've learned to ask since coming to the Dow Centre: 'how much does that cost'?

THE TEAM

Mr Thomas McConnaughy
Analyst

Tom graduated in 2012 from UCSB with an undergraduate degree in chemical engineering. Following graduation, he worked as a project engineer at Baxter International. The work focused on specification, installation and commissioning of equipment. During his time with the Dow Centre, Tom has worked on projects involving chemicals and energy. Concerning chemicals, Tom is the project manager of the Dow Centre's program for improving sustainability of global methane utilisation, focusing on finding an economic opportunity for natural gas reserves. Tom is also engaged in TEA and process modelling of radiation chemistry involving photochemical process source economics. Along with Dr Diego Schmeda, TEAs of the design and costing of molten salt nuclear reactor chemical processing systems and core designs as well as improving the value proposition of the nuclear power industry were developed. Additionally, procedures for breaking produced water and tailings oil/water/solid emulsions from oil sands operations were investigated.

I enjoy working at the Dow Centre because it focuses on and asks the important questions regarding the world's economy and future sustainability.

Mrs Mojgan Tabatabaei
Analyst

Mojgan joined the Dow Centre to develop new process schemes by focusing on sustainability in energy and economics. She has a Master's Degree in Chemical Engineering from The University of Tehran and over 16 years of industrial engineering experience as a process designer in Engineering Consultant Firms, mostly in oil and gas processing. Mojgan was involved in several projects from Conceptual Design, Front End Engineering Design and mega scale EPC projects as a Senior and Lead Process Engineer in South Pars Gas Condensate Filed in the Persian Gulf. She has extensive expertise in energy-efficient design and cost effective solutions especially in gas treatment and recovery processes. Mojgan is currently involved in a Dow Centre project on global methane utilisation and in halogenation based projects. She is developing thermochemical and photochemical processes schemes by building simulation models, equipment sizing and capital cost estimation to perform techno-economic analysis and identify an economical process scheme.

I really enjoy working with highly talented, dedicated and ambitious people in a friendly environment. I am highly motivated by and interested in contributing to innovative and sustainable technology.

Mr Conor Young
Analyst (until August 2015)

Conor studied a Bachelor of Mechanical and Materials Engineering (Hons) at The University of Queensland, graduating in July 2014. During his time at the Dow Centre Conor worked on the mechanochemical synthesis project, which investigated the possibility of producing valuable chemicals during ore grinding operations. Along with Mr Tom McConnaughy, Conor completed a paper detailing a TEA of compressed air energy storage in four unconventional applications. He also partnered with Tom to develop an equipment costing and complexity framework. In addition to his research tasks, Conor also assisted with the organisation of Centre events, website maintenance and the update of media content.

THE TEAM

Mr Brett Parkinson
Research Assistant

Brett graduated in 2014 from The University of Queensland with a Bachelors and Masters of Chemical and Materials Engineering (Hons). Following graduation, Brett worked temporarily as a consulting research officer for the Dow Centre, focusing primarily on process modelling of radiation chemistry, reactive distillation and halogen chemistry.

Brett has recently returned to the Dow Centre on a full-time basis, where the focus of his work will be on improving sustainable energy production from methane through minimising greenhouse gas emissions in hydrogen production.

I have no idea how much that will cost, but I imagine it's going to be expensive – designing every new process.

Mr Lucas Rush
Research Assistant

At the end of 2015, Lucas graduated with a dual Bachelor's degree in Chemical Engineering and Mathematics from The University of Queensland. During his undergraduate degree Lucas completed a research thesis on the applicability of using gamma rays as an initiation source for chemical production under the supervision of Professor Eric McFarland. This work has led to a casual position at the Dow Centre working on methane utilisation projects.

I enjoy working on complicated problems with huge potential benefits with a dedicated and hard working team!

Mrs 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 techno-economic analysis of Solar Energy in Australia to uptake the sustainable power generation while minimising public subsidies. The Dow Centre provides a unique collaboration space for Sara's multi-disciplinary project. Her aim is to become part of the UQ researcher and lecturing community.

Ms Julia Mueller
MPhil Student

Julia was awarded a Bachelor's of Science in Chemical Engineering with a minor in Environmental Engineering and research distinction in 2012 from The Ohio State University in the USA. She has an industrial background in electrochemistry, materials science engineering and process economics from working in solid oxide fuel cell private R&D and industrial electronics recycling. She has a research background in wastewater treatment engineering and a focus in waste to resource engineering. Her current work at the Dow Centre focuses on waste to resource recovery using membrane separation science for organic wastewaters. Julia enjoys working at the Dow Centre because of the practical approach to engineering by beginning with a techno-economic analysis of the process in conjunction with the literature review, followed by the scoping study in the lab. Her work will contribute to the water recovery and organic resource recovery goals of private industry.

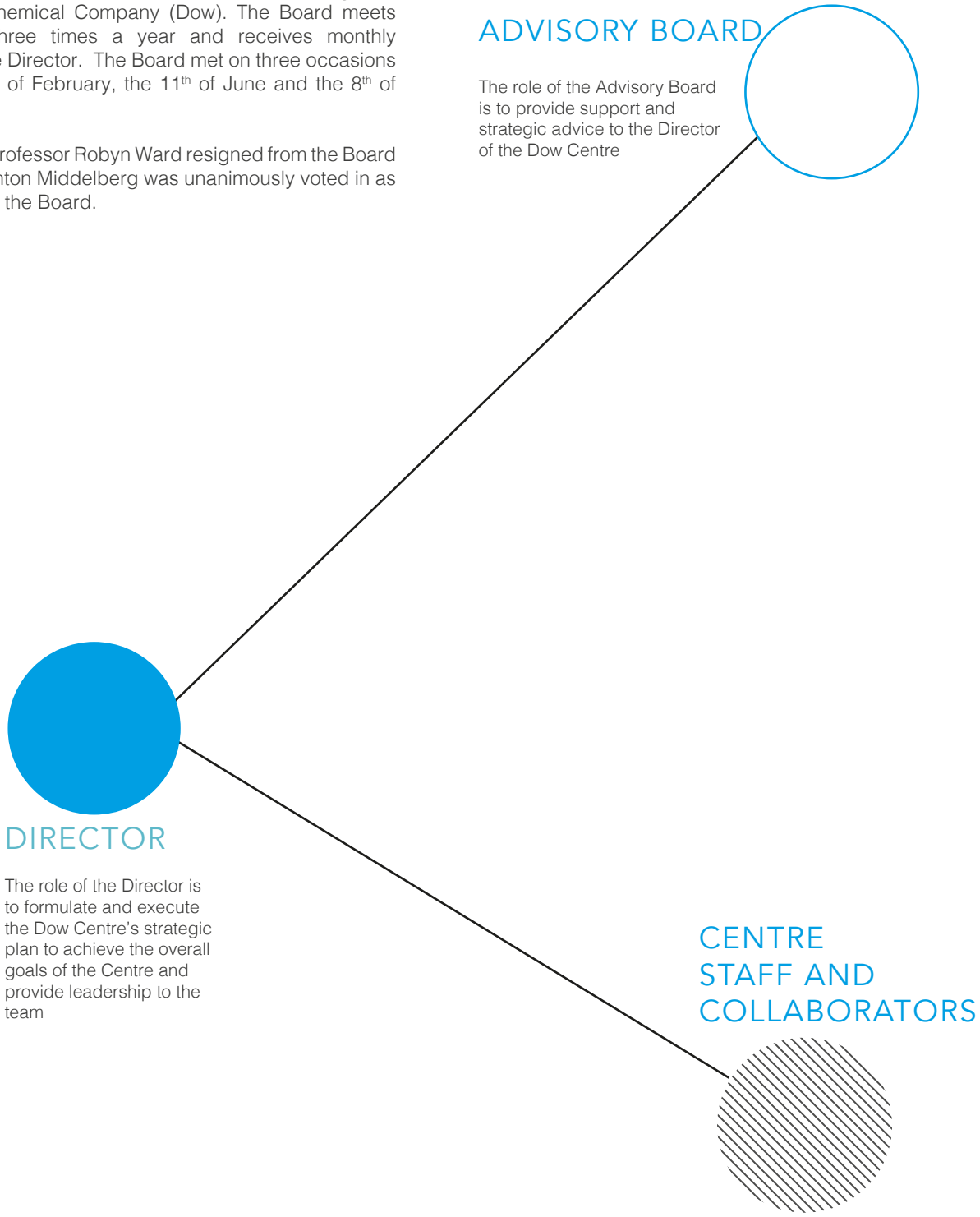
The harder I work, the more luck I seem to have (Thomas Jefferson).

CENTRE STRUCTURE

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 and receives monthly updates from the Director. The Board met on three occasions in 2015, the 12th of February, the 11th of June and the 8th of October.

In August 2015 Professor Robyn Ward resigned from the Board and Professor Anton Middelberg was unanimously voted in as her successor to the Board.



BOARD MEMBERS

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.

Professor Høj is Co-Deputy Chair of the Strengthened Export Controls Steering Group, member of the edX University Advisory Board and in 2014 was appointed as a senior consultant to Hanban in the Oceania Region.

He served on the CSIRO Board 2011-2014, a member of Australian Research Committee (ARCom) 2012-2014, a private member of the Prime Minister's Science Engineering and Innovation Council (PMSEIC) from 1999-2004, and as an ex-officio member from 2006-2007.

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 Robyn Ward AM FAHMS

Deputy Vice Chancellor Research
The University of Queensland
(Board member until July 2015)

Professor Ward is the Deputy Vice-Chancellor (Research) at The University of Queensland, where she leads the University-wide research portfolio.

Professor Ward graduated from the University of New South Wales with a MBBS (Hons 1) in 1984 and then trained as a physician and a scientist, gaining fellowship of the Royal Australian College of Physicians in 1991 and a PhD in Medicine at UNSW in 1994. She previously held positions at The University of New South Wales as Professor of Medicine, Clinical Associate Dean at the Prince of Wales Clinical School (UNSW) and Head of the Adult Cancer Program at the Lowy Cancer Research Centre. She was also Director of the Comprehensive Cancer Centre at the Prince of Wales Hospital in Sydney.

Professor Ward has demonstrated sustained translational and clinical research performance at the highest level.

As Director of the Translational Cancer Research Centre, she has worked with a network of universities and hospitals to pursue the translational cancer research objectives of the Cancer Institute of NSW. Her contributions to medical research have been acknowledged through a number of awards, including a membership of the Order of Australia, awarded in 2013.

Professor Ward has contributed to the development of Commonwealth and NSW health policy, including through her current roles as Chair of the Commonwealth Medical Services Advisory Committee and member of the Pharmaceutical Benefits Advisory Committee. She is currently Co-Chair for Global Genomics Medicine Collaborative (G2MC), which is hosted by the Institute of Medicine of the National Academies in Washington, and seeks to foster global collaboration in demonstrating the real world value of medical genomics to government and industry. She is also on the council of the NHMRC.

Professor Anton Middelberg

Pro-Vice Chancellor (R&I)
The University of Queensland
(Board member from August 2015)

Professor Middelberg is the Pro Vice-Chancellor (Research and International) at The University of Queensland, where he leads key aspects of the university-wide research and internationalisation portfolio. He obtained his Bachelor (1989) and PhD (1993) degrees from the University of Adelaide and his Master of Arts from Cambridge (2001).

After appointment as the youngest lecturer in engineering at the University of Adelaide and a Fulbright Fellowship at UC Berkeley, he accepted a position at Cambridge University. There he was rapidly tenured and promoted twice against quota to become the Reader in Biological Engineering. In this role he was also member of the Governing Body of Selwyn College and a Fellow of the Cambridge-MIT Institute.

In 2003, he returned to Australia as a Federation Fellow of the Australian Research Council (ARC) to progress his research into bio-inspired nanotechnology. His research into virus-like particle and nanoemulsion self-assembly has attracted more than $10million in research funding since 2003, including from the ARC, National Health and Medical Research Council (NHMRC) and the Bill and Melinda Gates Foundation.

BOARD MEMBERS

Dr Weiguang Yao

Chief Technology Officer, Asia Pacific R&D
Global Director, New Ventures for Asia Pacific, Middle East and Africa
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 make sure Asia-Pacific resources align with regional growth opportunities. He represents Dow R&D in the Asia-Pacific region. As Global Director for New Ventures in Asia Pacific, Middle East and African regions, he identifies and prioritises Dow's long-term new ventures and technology opportunities in the regions, helping define how Dow can further expand its value capture in these markets by building on existing capabilities. 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.

Dr Yao is a graduate of Yamagata University in Japan with a doctorate in polymer science and engineering, a master degree in chemical engineering from East China University of Science and Technology and a bachelor degree in physics from Yancheng Normal University in China. He holds 17 patents and a patent application, including 7 US granted patents and is the author of numerous publications.

Mr Tony Frencham

Managing Director and Regional President, Australia & New Zealand
The Dow Chemical Company

As Managing Director and Regional President, Australia & New Zealand, Mr Tony Frencham is the geographic leader for Dow in Australasia, responsible for country operations and business development.

With a business career spanning over 30 years, and the past 27 six years with Dow, Mr Frencham has served in a variety of business and executive roles in Asia, Europe, the United States, the Middle East and Australia.

Among a number of other roles, he is currently Board Vice Chairman of the Plastics and Chemicals Industries Association, a founding CEO member of the Australian Advanced Manufacturing Council and a foundation member of the Victorian Male Champions of Change.

Mr Frencham earned a Bachelor of Applied Science with Distinction (Chemistry) from LaTrobe University in 1982, a Graduate Diploma in Applied Polymer Science from Monash University in 1987, and a Postgraduate Diploma in Management from Deakin University in 1994.

Mr Noel Williams

Specialist Manufacturing Advisor, (Alumni Representative)

After a career with Dow spanning 36 years, Mr Noel Williams currently works in consultancy as a Specialist Manufacturing Advisor. Most recently in his career at Dow, Mr Williams was appointed as Vice President to lead Dow's Business Development efforts in Asia Pacific while previously he had been President of Dow in South East Asia, Australia and New Zealand, all based in Singapore.

After graduating in Chemical Engineering from The University of Queensland, a career with Dow began with assignments in manufacturing in Australia, the USA and Hong Kong, in plastics and chemicals technologies. Upon returning to Australia, he held responsibilities in a variety of plant management roles, Manufacturing Manager and Operations Director for Dow Australia, which led to active participation in the Australian industry, interface with the local community and participation in Industry / Government task forces.

Mr Williams is a past Chairman of the Board of the Institution of Chemical Engineers (IChemE) in Australia and was a Governor and Treasurer of the American Chamber of Commerce in Singapore. He is also a past President and Director of the Australian Plastics and Chemicals Industry Association. Mr Williams serves on the UQ School of Chemical Engineering Advisory Board.

BOARD MEMBERS

Professor Peter Gray

Director, Australian Institute of Bioengineering and Nanotechnology, The University of Queensland

Professor Peter Gray was appointed the inaugural Director of the Australian Institute of Bioengineering and Nanotechnology (AIBN) at UQ in 2003. Previously, he was Professor of Biotechnology and Director of the Bioengineering Centre at UNSW and a Senior Principal Research Fellow at the Garvan Institute of Medical Research in Sydney.

Professor Gray has had commercial experience in the USA working for Eli Lilly and Co and for the Cetus Corporation, as well as previously holding academic positions at University College London and at the University of California, Berkeley. His research interests are focussed on engineering mammalian cells to produce the complex proteins called biologics, which are gaining rapid acceptance as human therapeutics and on developing human stem cells bioprocesses suitable for clinical application. Professor Gray was one of the founders and is a past President of the Australian Biotechnology Association, AusBiotech. He is a Fellow of the Australian Academy of Technological Sciences and Engineering (ATSE) and of the Australian Institute of Company Directors and has been named as one of Australia's 100 Most Influential Engineers.

He is a Vice-President of ATSE and serves on the Boards of Biopharmaceuticals Australia Pty Ltd, Institute for Photonics and Advanced Sensing (IPAS), ACYTE Biotechnology Pty Ltd, Stem Cells Ltd, ECI Inc, New York and a number of State and Federal Government Councils and Committees.

Professor Ove Hoegh-Guldberg FAA

Director, Global Change Institute, The University of Queensland

Professor Ove Hoegh-Guldberg is Director of the Global Change Institute and Professor of Marine Science at The University of Queensland, Brisbane and Deputy Director of James Cook University's Centre for Excellence in Coral Reef Studies.

Professor Hoegh-Guldberg is a global expert on environmental change and marine ecosystems and is one of the world's most cited authors on climate change with more than 15,000 citations from >250 papers, books and patents. He is also a dedicated scientific communicator on the threat posed by ocean warming and acidification, first raising the alarm with respect to the seriousness of climate change for coral reefs in a landmark paper published in 1999. Ove is the Coordinating Lead Author for the 'Oceans' chapter of the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.

Working with Sir David Attenborough, Sylvia Earle, Tom Brokaw, Philippe Cousteau and many others, Professor Hoegh-Guldberg has attempted to take education beyond the walls of academia to millions. In 2014 alone, he educated over 2000 students through a massive open online course. He has received the Eureka Prize, a Queensland Premier's Fellowship and the 2014 Climate Change Award (Prince Albert II, Monaco) and is currently an ARC Laureate Fellow and member of the Australian Academy of Science. He is also Chief Scientist of the Catlin Seaview Survey, which is producing the largest baseline of coral reef health globally.

Professor Peter Halley

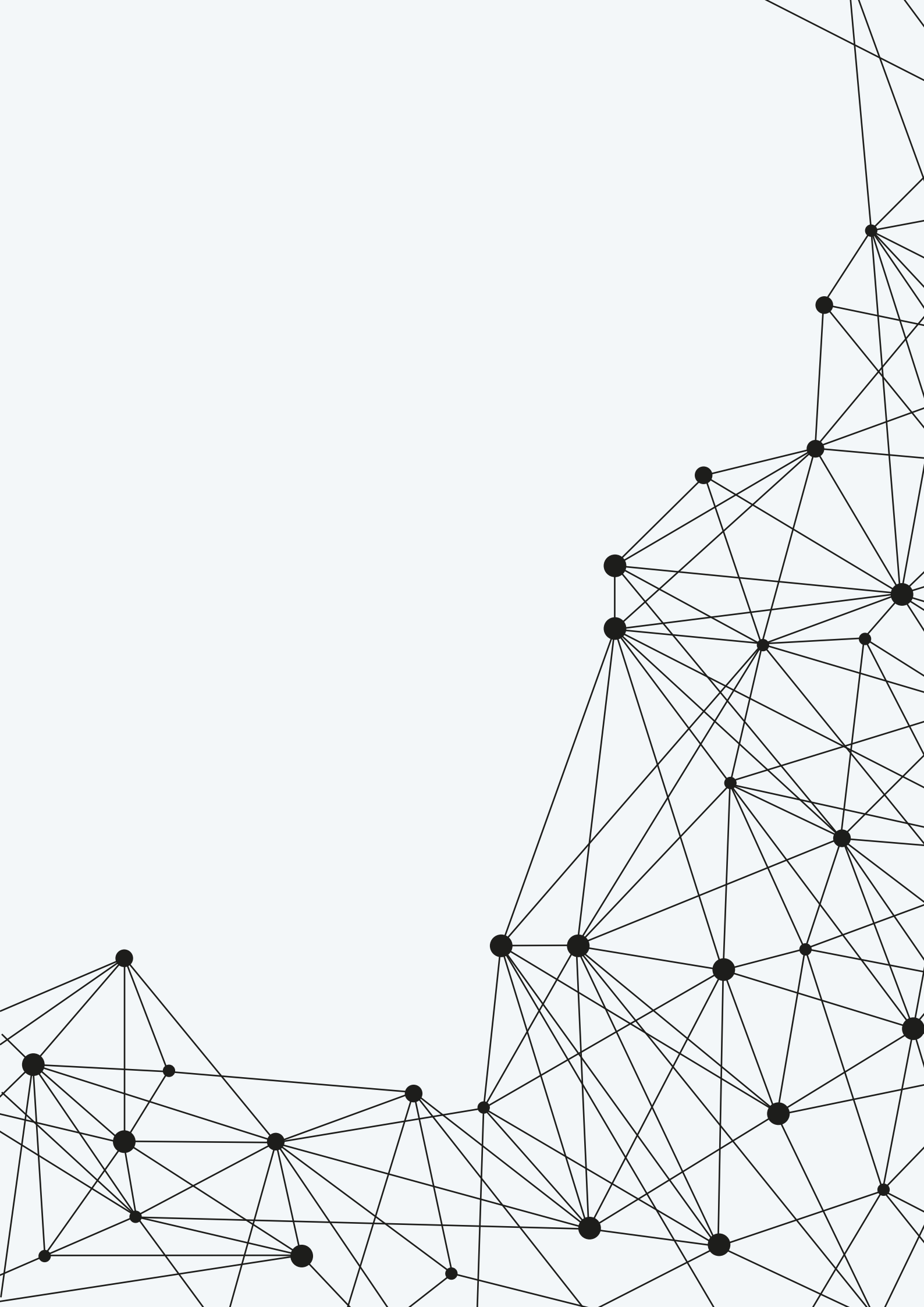
Head, School of Chemical Engineering, The University of Queensland

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 works at the translational research interface between universities and industry. He has worked in industry (SRI international, Sola Optical, Moldflow), has worked in three cooperative research centres (CRCs), has acquired and managed continuous government and industry research projects since 1994, was heavily involved in the spinoff of Plantic Technologies from the CRC food packaging in 2002 and was involved in the research that led to the TenasiTech (TPU nanocomposite) spinoff from UQ in 2007.

Professor Halley leads the CHPP - a virtual cluster of over 80 academics, researchers and students across UQ. In the CHPP he leads a processing research group (CHPP-processing) of 40 academics, researchers and industry partners focusing on the rheology, processing and product design of biopolymers, nanostructured polymers and high value engineering polymers.

Professor Halley is a fellow of the Institute of Chemical Engineers (IChemE) and a fellow of the Royal Australian Chemical Institute (RACI). Professor Halley is on the editorial board of Green Materials, Plastics, Rubbers and Composites, Starch/Starke and the Journal of Renewable Materials.



PERFORMANCE SUMMARY

2015

PERFORMANCE SUMMARY

24

INTERNATIONAL ORGANISATIONS VISITED

6

INDUSTRY PARTNERS

16

CONFERENCE PRESENTATIONS

INNOVATION 2015

- Identification and initial laboratory verification of a molten salt process option to reduce the cost and eliminate CO_2 generation from methane conversion to liquid chemicals.
- Generating highly visible activities and public discourse in promotion of nuclear power as a potentially game changing means of producing electricity and heat without carbon dioxide and progress on the conceptual design of an ultra-safe, low-cost molten salt reactor core design.
- Developing techno-economic analyses of flow batteries in electrical energy storage applications, solar hydrogen production and small-scale methane conversion systems.

COMMERCIAL ACTIVITIES

The Dow Centre contributed to the technology development for a wearable sensor application to healthcare in one spin-out: 7th Sense Care Pty Ltd

Currently working to raise funding for a pilot program with a Brisbane-based care provider.

THE DOW CENTRE IS COMMITTED IN ITS VISION TO IDENTIFY AND FOSTER INNOVATION

6 outreach events

Organised, including movie nights, student forums and UQ-wide events

$624,161
External funds raised

1
Patent filed in 2015

5
Techno-economic assessments

PERFORMANCE SUMMARY

EXTERNAL FUNDING
2014-2015

$624,161

- Australian Research Council
  Linkage Project (LP150100862)
  $159,661 ARC LP.
  $100,000 Dow Chemical (raised November 2014, leveraged here for LP)
  [Note: November 2015, due to a change in its global strategy, The Dow Chemical Company withdrew from the project. The Dow Centre is currently looking for another partner (Deadline 30th of June 2016)].

- Israel Chemicals Limited (ICL):
  $440,000 (overheads waived)
  $120,000 Cash contribution from the Dow Centre (not included in total raised figure)
  The funding will be paid over two years:
  2015: $220,000 ICL + $60,000 Dow Centre
  2016: $220,000 ICL + $60,000 Dow Centre

- Australian Meat Processor Corporation LTD (AMPC):
  $24,500 (attracts overheads), payable in 2016.

Total external funding raised by the Dow Centre during since its inception: $1,409,661.

FUNDING COMMITTED

DOW DONATION
77%

UQ CONTRIBUTION
13%

EXTERNAL FUNDING
10%

By 2018 the Dow Centre aims to raise sufficient external funding to be operationally independent from the Dow donation

LOOKING AHEAD

2018

Towards the end of the year the Dow Centre will have projects in all phases of development and will raise sufficient funding to operate independently from the Dow donation.

2017

The first projects will mature and the Dow Centre will start to raise more external funding.

2016

Prof Chris Greig is appointed to lead the Dow Centre as its new Director. Prof McFarland maintains close collaboration with the Dow Centre on a part time consultancy basis. The Dow Centre will focus on further developing relations with Industry in the Asia-Australia region.

2015

Activities start to centre around 3 core programs and a small number of other technical projects. TEA is incorporated in all research activities and the Dow Centre focusses on technologies that lead to cost effective, scalable innovation. Prof McFarland resigns for family reasons and returns to his previous position at the University of California Santa Barbara at the end of the year.

2014

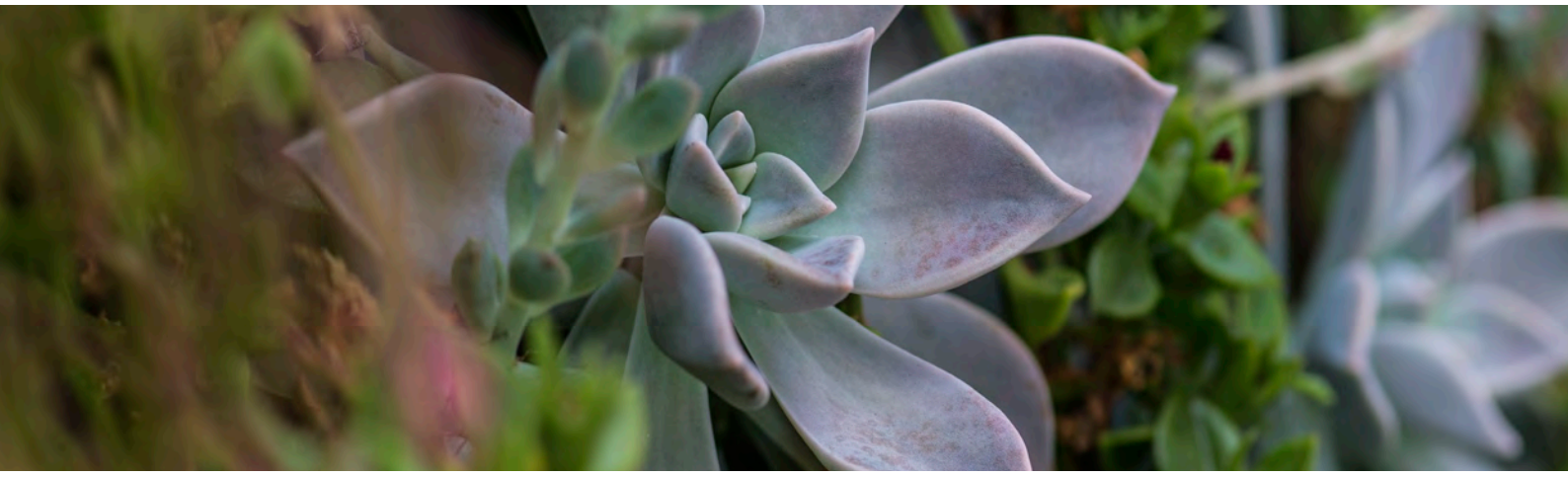
Prof McFarland takes up his position at UQ, more team members are appointed and mid-August the team moves into newly renovated offices. Several ideas for projects are investigated and the first initiatives to stimulate innovation take shape. In December the Dow Centre offices are officially opened by Dr Andrew Liveris, the Hon. Mr Ian Macfarlane and Prof Peter Høj in a festive ceremony at the Dow Centre's premises.

2013

After an international search in June Prof Eric McFarland is appointed as the inaugural Director of the Dow Centre and the Dow Chair. His vision, mission and strategy for the Centre are accepted by the Board and the first team members are appointed. Work on the renovation of allocated space begins later in the year.

2012

UQ and the Dow Chemical Company (Dow) sign an agreement to establish the Dow Centre for Sustainable Engineering Innovation and the Dow Chair for Sustainable Engineering. Dow donates 10M USD over a period of five years and UQ commits to another $2M AUD.



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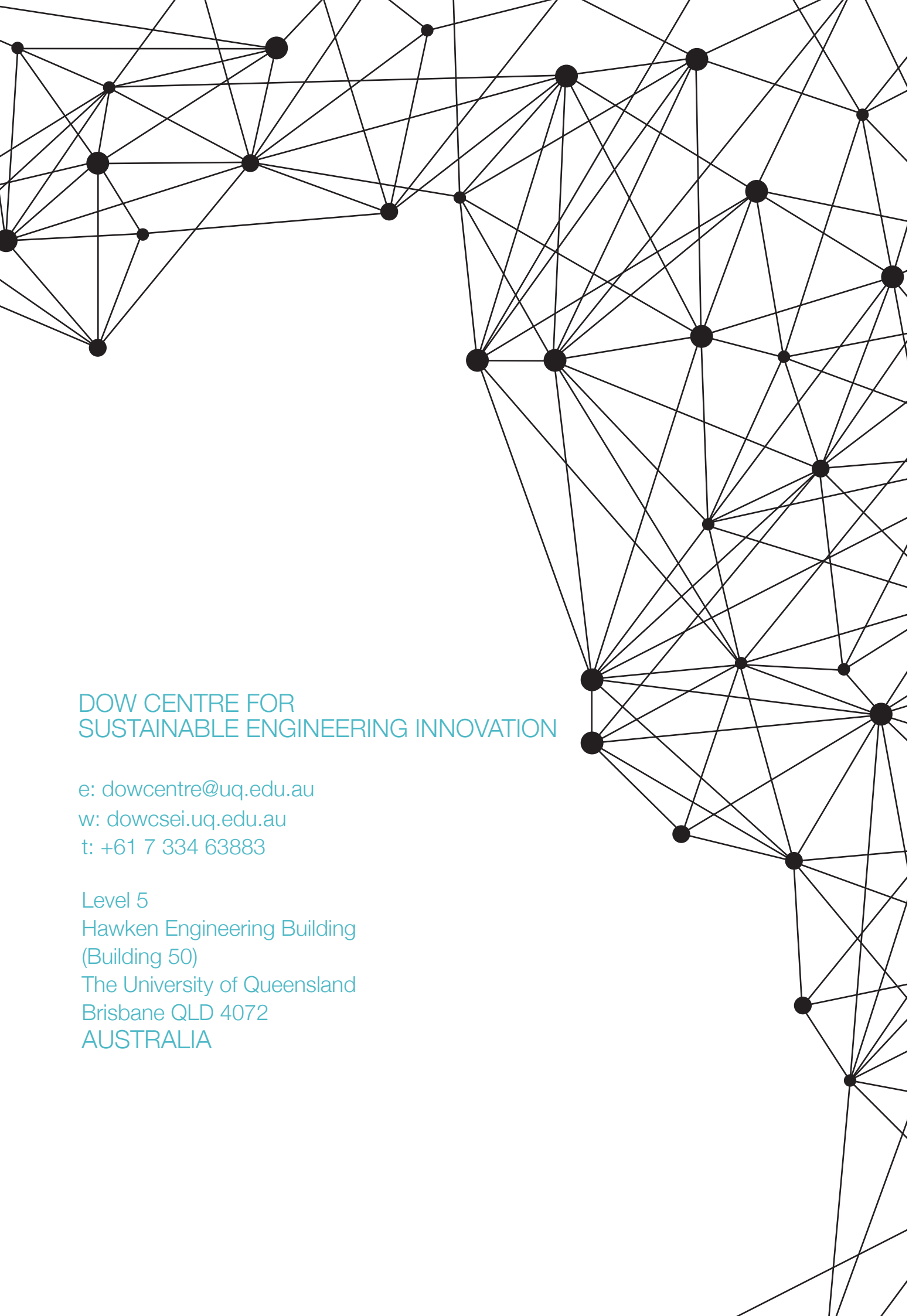

DOW CENTRE FOR
SUSTAINABLE ENGINEERING INNOVATION

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