School of Chemical Engineering
Research Perspective
The School of Chemical Engineering at UNSW Australia is a powerhouse of innovative engineering research. We provide innovative solutions to technically complex challenges in the production, processing and management of energy, food, health and water resources. We value and encourage industry collaboration and see it as a key-contributing factor to the School’s strength.

As a foundation school of UNSW Australia, the School of Chemical Engineering has a long and proud history. This includes innovation and global impact spanning membrane technology, catalysis, vanadium batteries, polymers and nanomaterials. Our researchers are world class and many of our graduates have emerged to become technology entrepreneurs or leaders of global companies.

This publication provides a snapshot of our current research expertise as it evolves towards addressing the global challenges facing society today. It also highlights some of the existing collaborations we have with our partners from industry.

We place enormous importance on the transfer of our research into practice and each year our academics and research centres work with dozens of businesses, government and community organisations on specific industry related projects. Some examples of our industry partnerships can be found on pages 14–21.

Working with our partners in industry helps drive the application and impact of our research and supports the relevance of our learning and teaching programs across industry.

More detailed information about our research expertise and academic staff can be found on the School’s website che.unsw.edu.au, where you can also subscribe to the School’s newsletter.

We welcome all enquiries about engagement and partnership opportunities and I invite you to connect with us to explore further ways of linking our remarkable researchers and facilities with your needs and ambitions.

Professor Vicki Chen
Head of School
UNSW Chemical Engineering
Sustainable and biodegradable polymers

We develop unique polymerisation techniques based on the use of visible light as the sole energy source driving the synthesis of biodegradable macromolecules with well-defined architectures and functionalities. Our expertise also lies in the precise design of these polymers toward the controlled and targeted delivery of therapeutic agents for the treatment of cancer.

Associate Professor Cyrille Boyer

Smart coatings for lubrication and adhesion

Lubrication and adhesion are both important for industry and in biological systems. We are learning how molecular layers of soft matter behave in confined spaces. By understanding the molecular basis of human joint lubrication, we are designing better lubricants and adhesives for moving parts in microtechnology and plant machinery.

Dr Stuart Prescott

Polymeric carriers and nanomaterials

We develop environmentally friendly processes relying on the use of carbon dioxide as a solvent for the synthesis of novel polymeric materials with unique physical and chemical properties. These polymeric materials are designed to act as nanoreactors for controlled reaction processes; carriers for drug delivery and advanced materials for paint formulations. They are also being designed to capture water directly from the atmosphere.

Professor Per Zetterlund

Engineering “Smart” fluids

Our aim is to design novel complex fluids with unique flow properties that mimic biological fluids or enable enhanced oil recovery.

Associate Professor Patrick Spicer
Advanced products and processes

A key aim of UNSW Chemical Engineering is to implement advanced technologies leading to improved, safer and more efficient processes to benefit the global community while lessening environmental impact. Building on our core expertise, we are developing advanced products and processes across water treatment, renewable energy, food and industrial chemicals. We are research leaders in the area of water reuse and treatment and we have developed advanced models for process control. Projects we’ve worked on range from developing intelligent instrument schemes for monitoring industrial aluminium smelting processes, to creating novel technologies to preserve and increase nutritional content in packaged and processed foods.

Intelligent process control for distributed energy systems

Owing to the intermittency of renewables, their integration to the grid is problematic beyond 20% of installed capacity. We are developing advanced processes to regulate distributed energy storage systems to minimise the imbalance of energy demand and supply from renewables. Our expertise lies in our unique integration of nonlinear control theory with a distributed optimisation approach to reduce the pressure on electricity transmission networks.

Professor Jie Bao

Modelling ultrasonic reactors for food processing

Ultrasound has the potential to lead to continuous food processing under mild conditions of temperature while better preserving essential nutrients. To enable the large scale implementation of these novel processes, we are developing accurate numerical models mimicking the complexity of ultrasonic processing. Our aim is to facilitate the design, optimisation and adoption of industrial scale plasma based equipment.

Dr Francisco Trujillo

Eradicating biofilms with cold plasma

Food borne diseases and contamination of food along production chains are common problems faced by industry. We are developing novel air plasma technology to eradicate biofilms while preserving food nutrients. Our expertise combines the physics of plasma, novel plasma reactor design, and microbiology.

Dr PJ Cullen

Retention of fresh notes in product drying

Drying is one of the most convenient ways to preserve food. However, this often leads to a loss in sensory attributes because of degradation of aromas and flavours. We are developing advanced drying processes for specific foods and modelling methods to optimise technologies, including heat pump dryers, freeze dryers, refractance window dryers and microwave vacuum dryers.

Dr Robert Driscoll
Harvesting sunshine to create sustainable fuels

We develop next generation hybrid photo-electro catalysts that harness solar energy to transform carbon dioxide and water into sustainable fuels. Our expertise includes designing hetero-structured catalysts to effectively harvest solar light and translating these findings into greener manufacturing processes involving hybrid photo-catalysis.

Professor Rose Amal
Dr Yun Hau Ng

Predicting materials’ behaviour

Our expertise in computational modelling helps us facilitate material design. High performance simulation, for example, predicts how charging electroactive materials can enable the capture and storage of key target molecules (such as carbon dioxide and hydrogen) with unprecedented control.

Professor Sean Smith

Storing the ultimate clean energy carrier

Hydrogen is the ultimate clean energy carrier providing unlimited possibilities to generate energy on demand. Through nanotechnology we are aiming to develop better materials to safely store high-density hydrogen. These storage materials also find application in switchable mirrors, metal-air batteries and catalysis.

Associate Professor Kondo-François Aguey-Zinsou

Sustainable energy storage technologies

The large scale deployment of renewable energy and the shift towards electric vehicles will require the development of new battery technologies. We are developing alternative battery concepts with high energy density, affording greener and more sustainable energy storage technologies post Lithium-ion. Our expertise lies in the synthesis and design of advanced electrode materials.

Dr Da-Wei Wang
Micronutrient fortification of foods

One way to combat micronutrient deficiencies is to fortify cereals with multiple micronutrients. However, this can lead to synergistic or antagonistic effects. We are developing sophisticated ex-vivo and in-vivo techniques to accurately inform the development of effective fortification methods.

Associate Professor Jayashree Arcot

Tackling food allergies with molecular design and control

Food allergies are an emerging epidemic currently affecting 10% of the world’s population. We are developing a treatment based on novel immunotherapy techniques enabling improved efficacy and safety.

Associate Professor Alice Lee

Improving health using Australian native plants

Australian native plants have many hidden health-promoting bioactive components. We have launched the search, extraction, identification and elucidation of bioactivities within these components with the aim of developing effective methods for their practical use and application.

Associate Professor Jian Zhao

Designing better carriers for drug delivery

High performance materials simulations are allowing us to understand how drugs interact with dendrimer and polymer carrier molecules. Our core expertise helps experimentalists design effective carriers to package and deliver drugs and bioactive components to targeted cells in-vivo.

Professor Sean Smith

Food and health issues are global challenges. We are committed to improving global health by developing innovative food processes that deliver advanced nutritional content and naturally occurring bioactive elements. In addition, we are dedicated to addressing issues related to food safety, accessibility and allergens.

Our approach is multidisciplinary and involves food scientists, processing technologists, engineers, microbiologists, food chemists, food rheologists and nutritionists. Our experts are engaged with industry and government agencies and are focused on delivering technologies to improve food processes, nutrition, safety and availability.
Growing environmental concerns about pollution, greenhouse gas emissions and access to safe water means more efficient environmental technologies are needed. Our world class researchers have global reach, working in close collaboration with partners in industry, technology manufacturers and health regulators to provide solutions for these critical problems.

Our environmental technology research has advanced expertise in membrane technologies and their applications in water and wastewater treatment, dissolved air flotation and separation processes for the capture and conversion of carbon dioxide.

### Advancing membrane technologies for gas separation and water treatment

Novel nanocomposite polymeric membranes incorporating the latest generation of materials, offer new opportunities for advanced gas separation and water treatment. We are developing ultrathin coatings on polymeric scaffolds to form robust superhydrophobic or superhydrophilic surfaces and materials with enhanced separation performances and efficiency. Novel membrane processes for treatment of recalcitrant effluents are also a focus.

**Professor Vicki Chen**

### Enhancing the performance of wastewater plants

Our advanced numerical modelling techniques (based on computational fluid dynamics and expertise in life cycle analysis) provides industry with accurate tools to design, evaluate and effectively implement membrane processes for the recovery of water and nutrients in wastewater systems.

**Professor Greg Leslie**

### Validation guidelines for water recycling processes

Our expertise is providing a platform for the development of validation guidelines for the use of membrane bioreactors (MBR) for wastewater recycling across Australia. The aim is to facilitate the deployment and implementation of effective MBR technology across industry to supply safe water to the community.

**Associate Professor Pierre Le-Clech**

### Energy and safe water from microbial separation systems

By combining our fundamental understanding of microbial systems with the latest monitoring techniques we are developing effective and efficient separation processes to remove microbial systems and algae from waste and drinking water. Our expertise extends to the harvesting and conversion of these algae into biofuels through magnetic excitation.

**Dr Rita Henderson**

**Dr May Lim**
Our industry partners include Australian and international companies spanning across energy, food and health, water and manufacturing.
Industry partnership

Improving the health of a nation

Partnership in summary
Partner: Goodman Fielder Ltd
Type of partnership: Contract research
Funding: $300,000 in cash and in-kind support.
Collaborating since: 2015
Purpose: To demonstrate how and why the mandatory fortification of wheat flour is of critical importance to the future wellbeing of Papua New Guinea (PNG) society.
Outcomes: To increase the nutritional value of wheat flour and other products that the population consumes to combat micronutrient malnutrition.

Goodman Fielder, one of the major flour millers in Papua New Guinea (PNG), is working with nutrition and food science expert Associate Professor Jayashree Arcot from the School of Chemical Engineering to ensure public nutrition is improved through micronutrient-fortified wheat flour.

“Micronutrient malnutrition is one of the most debilitating non-communicable conditions in any population,” says A/Prof Arcot, who has extensive experience in fortifying foods with micronutrients for human consumption. “It contributes to a vicious cycle of poor health and depressed productivity as seen in PNG.”

The last national nutrition survey (conducted in PNG in 2005) identified an alarming 44% of children between six months and five years suffering from chronic energy deficiency and stunting; 26% suffering a vitamin A deficiency; and 48% suffering anaemia due to iron deficiency.

Carol Colyer, a UNSW alumna who works for Goodman Fielder R&D as their Regulatory and Product Guidance Senior Manager, approached A/Prof Arcot in 2015 about a joint research project. Colyer wanted to tackle micronutrient malnutrition in PNG by fortifying wheat flour with some of the essential nutrients missing from the daily diet of the population.

“According to the Food and Agriculture Organization of the United Nations, adding nutrients to a food (fortification), for the purpose of preventing or correcting a demonstrated deficiency of one or more nutrients in the population, is one of the best-recognised interventions for the prevention and control of micronutrient malnutrition,” says A/Prof Arcot. “It can offer enhanced protection from a range of disabling and diseases, and help children grow and learn. Systematic scientific studies are required to make sure the added vitamins remain stable in a tropical environment and are efficiently absorbed by the target population under different nutritional status conditions.”

The project is looking to fortify selected wheat based products with eight nutrients (iron, zinc, vitamin A, lysine, thiamin, riboflavin, niacin and folic acid) and study the interactions between the added nutrients, adjusting levels of addition based on these studies. They will then launch a nutrition intervention study in school children in PNG complemented by nutrition education programs for school children and their families.

“Our collaboration with Goodman Fielder will contribute significantly to the academic body of knowledge in regard to nutritional intervention studies and the assessment of key nutritional biomarkers,” A/Prof Arcot continues. “But essentially, we want to see on-the-ground results. We want to improve the health of the local population, with a particular focus on mothers, infants and children.”

“When considering who to partner with in our research in PNG, my natural choice was to first look to my alma mater for support. Picking up the conversation with Jayashree Arcot, it was immediately evident that she too shared our passion and hence our partnership progressed.”

Carol Colyer
Regulatory and Product Guidance Senior Manager, Goodman Fielder Ltd

Featured expert:
Associate Professor Jayashree Arcot

Associate Professor Jayashree Arcot is an expert in the area of food and nutritional science and Co-Director of the ARC Training Centre for Advanced Technologies in Food Manufacture. Her research in human nutrition is based on a food-based approach to tackling micronutrient malnutrition. She is active in industry and academia, sitting on panels and speaking at conferences, and has received considerable funding for her research. She has published widely and in 2013 was awarded the Australia-India Senior Visiting Fellowship by the Australian Academy of Science.
Industry partnership

Water supplies under pressure

Partnership in summary

Partner: Multiple partners including Water Research Australia, South Australia Water and Melbourne Water.

Type of partnership: Ongoing collaborations through ARC Linkage Projects and contract research.

Funding: $1.9 million since 2010 in ARC grants, plus additional financial and in-kind support from partners in the water industry.

Purpose: To improve the water quality in drinking and recycled water supplies impacted by algae and cyanobacteria or elevated organic matter content.

Outcomes: More sustainable, resilient and reliable water treatment processes and state-of-the-art online monitoring techniques.

With algal blooms costing an estimated $200 million of damage annually, Dr Rita Henderson and her research group at the bioMASS Lab in the School of Chemical Engineering assist their partners in the water industry by developing novel treatment and monitoring methods to assist in the management of impacted water supplies.

Australia’s water supplies are already under tremendous stress due to drought, climate change, population growth and pollution. But an additional challenge for the Nation’s water industry is an observed increase in algal bloom development and elevated organic matter content in our waterways.

Dr Henderson, who has more than 10 years’ experience in the area of algal and organic matter treatment and monitoring, says these problems cost millions of dollars to manage annually. The water industry has to contend with the possible release of toxins, and taste and odour compounds, from algae into the water supply, while waterways affected by increased organic matter content are at risk of producing potentially harmful disinfection by-products that result from reactions between organic matter during disinfection.

“It is critical that sustainable and robust water treatment technologies and associated monitoring techniques are developed and optimised to deal with these scenarios,” Dr Henderson says.

With the help of industry partnerships, ARC grants and other funding sources, Dr Henderson and her team have developed a novel dissolved air flotation process to treat algal blooms. “We’ve shown at pilot scale that we can treat high concentrations of algae effectively and efficiently, while reducing chemical consumption and waste stream volume,” she says.

“Our research has also led to a better understanding of the impact of algal and organic matter on treatment process performance and we have developed a method that uses fluorescence probes to monitor water quality. These probes can act as an early warning device.”

“For Water Research Australia it’s important that collaborative research projects engage with industry to ensure the transfer of knowledge and adoption of research outcomes, and Dr Henderson does this extremely well.”

Claire McInnes
Program Coordinator for Water Research Australia, a not-for-profit company which undertakes collaborative research on all aspects of drinking water, recycled water and wastewater. She has worked with Dr Henderson on a number of water quality research projects.

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New approaches improve aluminium smelting processes

Partnership in summary
Partner: Emirates Global Aluminium (Formerly Dubai Aluminium Company)
Type of partnership: Contract research
Collaborating since: 2009
Funding: $528,000 in cash, plus significant in-kind contribution.
Purpose: To develop a low cost, low maintenance and robust approach for online monitoring and analysis of the aluminium smelting process.

Outcomes:
1. An intelligent instrumentation scheme for online monitoring and analysis.
2. Algorithms/software to detect, in real time, conditions that adversely impact energy and environmental efficiencies.
3. Two filed patent applications.

International process control expert, Professor Jie Bao from the School of Chemical Engineering, teamed up with world experts in electrochemistry, Professors Barry Welch and Maria Skyllas-Kazacos, to help Emirates Global Aluminium (EGA), one of the world’s largest aluminium smelters, improve the efficiency of their smelting operations.

The primary production of aluminium is highly energy intensive. With energy costs representing 22–36% of operating costs in smelters, it’s no wonder the industry is looking for more energy-efficient production technologies.

"In recent years, productivity and flexibility have become important economic drivers due to the changing cost structure for aluminium smelting. But unfortunately, operating practices modified to meet these requirements have increased the frequency of abnormalities, adversely impacting energy and environmental efficiencies," Professor Bao explains.

"This has led to a need to be able to monitor the operation of smelting cells online; estimate some key process variables that cannot be directly measured; and detect abnormal conditions in real time."

The partnership between EGA and UNSW started in 2009, when Professors Bao, Welch and Skyllas-Kazacos were working on a project funded by CSIRO. "We collaborated with EGA on a number of experimental studies with industrial operating cells and had such promising outcomes that EGA decided to fully fund this new research project," says Professor Bao. "This is a truly interdisciplinary project that was developed based on our expertise in process control and electrochemistry."

The project has resulted in some very useful outcomes for the aluminium industry. The first, which Professor Bao says is already implemented in a number of smelting cells in operation at EGA, is a cost-effective, low maintenance intelligent instrumentation scheme to monitor anode current distribution in real time. The second is the development of software to detect, in real time, conditions that adversely impact energy and environmental efficiencies. Two patents have been filed as a result.

"It was my personal pleasure to work with such a great team on this breakthrough project. I enjoyed the process and found the outcomes very valuable and useful not only for EGA but for the entire industry. The results have the potential to improve the efficiency of the aluminium smelting process from both a productivity and environmental point of view by decreasing the energy and manpower requirements."

Sergey Akhmetov
Vice President-Reduction, Emirates Global Aluminium
“We welcome all enquiries about engagement and partnership opportunities and I invite you to connect with us to explore further ways of linking our remarkable researchers and facilities with your needs and ambitions.”

Professor Vicki Chen
Head of School
UNSW Chemical Engineering