THE UNIVERSITY OF MELBOURNE

Melbourne Energy Institute

MEI Symposium 22

Friday, 9 December

Contents

Program

Date:	9 December 2022	**Time:**	8:30am – 5:00pm
Venue:	Glyn Davis Building (Building 133), Masson Road, University of Melbourne, Parkville VIC 3010		
Registration:	go.unimelb.edu.au/4m4e		
Cost:	Free	**Enquiries:**	mei-info@unimelb.edu.au

8:00-8:30am	**REGISTRATION AND COFFEE**

	OPENING PLENARY
	Lecture Theatre - B117
8:30-8:40am	**Welcome and opening of MEI Symposium 22** **Professor Michael Brear,** *Director*, Melbourne Energy Institute
8:40-9:35am	**Keynote Plenary: Paving the way to Australia's net-zero future** **Mr Daniel Westerman,** *Chief Executive Officer*, Australian Energy Market Operator (AEMO**)**

	STREAM 1 (MORNING) **Energy Systems** Chair: Prof. Pierluigi Mancarella, *Program Leader*	**STREAM 2 (MORNING)** **Energy Materials** Chair: Dr Christian Brandl on behalf of A/Prof. Wallace Wong, *Program Leader*
	Singapore Theatre - B120	**Malaysia Theatre - B121**
09:35-10:25am	**Keynote:** **Operational challenges of high renewable dominated grids and some perspectives** **Professor Tapan Saha**, *Professor, Leader of Power, Energy & Control Engineering, Leader of UQ Solar,* University of Queensland	**Keynote:** **Promising top cell candidates for Si-based tandem cells** **Professor Xiaojing Hao,** *ARC Future Fellow, School of Photovoltaic and Renewable Energy Engineering,* UNSW Sydney
10:25-10:50am	**MORNING TEA**	
10:50-11:20am	**The role of hydrogen in decarbonising a coupled energy system** **Mr Yimin Zhang,** *PhD candidate, Mechanical Engineering*, University of Melbourne	**The synergy of automated fabrication, testing and machine learning: Open access materials discovery platform** **Dr Maciej Adam Surmiak,** *Platform Engineer, Research Fellow*, Monash University
11:20-11:50am	**Thermo-mechanical energy storage options to decarbonise the Australian energy system** **Dr Andrea Vecchi,** *Research Fellow in Clean Energy and Clean Transport, Mechanical Engineering*, University of Melbourne	**New strategies in sustainable molecular assembly with flow chemistry and catalysis** **Dr Anastasios Polyzos**, *Senior Lecturer, Flow Chemistry and Catalysis, Chemistry,* University of Melbourne
11:50-12:20pm	**Facilitating DER Services using Operating Envelopes** **Dr Michael Liu,** *Research Fellow in Smart Grids,* University of Melbourne	**Cross-scale modelling of ion transport in nanoporous electrodes towards digital design of high-efficiency ionic devices** **Dr Peiyao Wang,** *Research Fellow in Nanoionics, Chemical Engineering,* University of Melbourne

	Stream 1	Stream 2
12:20-12:50pm	**Feasibility of energy community projects in Victoria: towards capturing their whole system value** **Ms Carmen Bas,** *PhD candidate in electric power systems,* University of Melbourne	**Computational materials engineering for selective electrochemical CO_2 reduction** **Dr Xing Zhi,** *Research Fellow in molecular modelling of carbon dioxide reduction, School of Mechanical Engineering,* University of Melbourne
12:50-1:30pm	**LUNCH & POSTER COMPETITION**	
	STREAM 1 (AFTERNOON) **Power Generation and Transport** Chair: Professor Richard Sandberg, *Program Leader*	**STREAM 2 (AFTERNOON)** **Hydrogen and Clean Fuels** Chair: Associate Professor Kathryn Mumford, *Program Leader*
	Singapore Theatre - B120	**Malaysia Theatre - B121**
1:30-2:20pm	**Keynote:** **Carbon-neutral fuels for decarbonizing combustion** **Associate Professor Yi Yang,** *Associate Professor, Mechanical Engineering*, University of Melbourne	**Keynote:** **Tailoring multifunctional catalysts for clean fuel synthesis** **Professor Karen Wilson,** *Professor of Catalysis, Centre for Advanced Materials and Industrial Chemistry, RMIT University*
2:20-2:50pm	**Rapid soil-structure interaction in sand for offshore energy applications** **Dr Shiaohuey Chow,** *Senior Lecturer in Geotechnical Engineering,* University of Melbourne	**Use of water injection to control autoignition and knock in a heavy-duty, hydrogen-fuelled, reciprocating engine** **Mr Joel Mortimer,** *PhD candidate, Mechanical Engineering,* University of Melbourne
2:50-3:20pm	**Air pollution from fossil fuels: A public health policy gap** **Ms Clare Walter,** *Honorary Research Fellow in Biochemistry and Pharmacology,* University of Melbourne	**Nitrogen and oxygen nucleation in cryogenic hydrogen mixtures** **Dr Eirini Goudeli,** *Senior Lecturer, Chemical Engineering,* University of Melbourne
3:20-3.40pm	**AFTERNOON TEA**	
3:40-4:10pm	**The role of high-fidelity simulations in designing more efficient compressors** **Mr Pawel Przytarski,** *Research Fellow,* University of Melbourne	**Ultra-high-performance solar water splitting with earth-abundant cocatalyst foils** **Dr Joshua Butson,** *Postdoctoral Research Fellow, Carbelec Project, Chemical Engineering,* University of Melbourne
4:10-4:40pm	**High performance computation of hydrogen-fuelled engines** **Dr Reza Yosri,** *Research Fellow in Clean Energy and Clean Transport, Mechanical Engineering,* University of Melbourne	**A greener pathway to CO_2 capture** **Dr Rebecca McQuillan,** *Research Fellow in Chemical Engineering,* University of Melbourne
4:45-5:00pm	**CLOSE**	

Plenary

Welcome

Professor Michael Brear

Director, Melbourne Energy Institute

Professor Michael Brear is a mechanical engineer and the Director of the Melbourne Energy Institute (MEI) at the University of Melbourne. MEI facilitates the University's research on the technical, economic, environmental and social impacts of energy.

Michael is a Fellow of the Australian Academy of Technology and Engineering, the Combustion Institute, Engineers Australia and the Australian Institute of Energy. He previously established the University's multi-disciplinary degree, the Master of Energy Systems. Prior to commencing at the University of Melbourne, Michael worked for ICI Australia (now Orica), and then undertook graduate studies at Cambridge University and post-doctoral research at the Massachusetts Institute of Technology.

Keynote: Paving the way to Australia's net-zero future

Mr Daniel Westerman

Chief Executive Officer, Australian Energy Market Operator (AEMO)

As Australia moves rapidly away from its dependency on coal generation, our energy future will be built on four pillars: low-cost renewable energy, taking advantage of the abundant wind, solar and hydro resources that Australia has to offer; firming technology like pumped hydro, batteries, and gas generation, to smooth out the peaks and fill in the gaps from that variable renewable energy; new transmission to connect these new and diverse low-cost sources of generation to our towns and cities; and grids capable of running, at times, entirely on renewable energy. In a keynote address, Mr Daniel Westerman explores the changes that need to occur to enable a smooth transition to a net-zero energy system, drawing from unique insights from AEMO's latest reports into Australia's energy system.

Mr Daniel Westerman commenced as CEO and Managing Director of AEMO in May 2021. He oversees AEMO's strategy and operations, including collaboration with market participants and policy makers.

Daniel is a chartered engineer and a business leader with significant experience in the energy sector. Under Daniel's leadership AEMO is planning for Australia's energy future while operating the system and markets of today in a rapidly changing energy landscape.

Prior to joining AEMO, Daniel held a variety of senior executive roles with London-listed electricity and gas utility, National Grid Plc. Most recently he served as Chief Transformation Officer and President of Renewable Energy, where he led the company-wide transformation program, and grew a large-scale renewable energy business in the United States. In previous roles he has been responsible for engineering, planning and operational control of the electricity transmission network across Great Britain, as well as the development of distributed energy systems, such as rooftop solar, storage and energy metering. Prior to joining National Grid Plc, he held positions with McKinsey & Company and Ford Australia.

Daniel holds degrees in Engineering and Mathematics from the University of Melbourne, and an MBA from Melbourne Business School. He is a Fellow of the Energy Institute and the Institution of Engineering and Technology, and a Fellow of the Institute of Directors.

Energy Systems

Chair

Professor Pierluigi Mancarella

Program Leader, Energy Systems, Melbourne Energy Institute

Professor Pierluigi Mancarella is Chair Professor of Electrical Power Systems at the University of Melbourne, Australia, and Professor of Smart Energy Systems at the University of Manchester, UK. His key research interests include techno-economic modelling and analysis of multi-energy systems, grid integration of renewables and distributed energy resources, energy infrastructure planning under uncertainty, and security, reliability, and resilience of low-carbon networks.

Pierluigi is an IEEE (Institute of Electrical and Electronics Engineers) Power and Energy Society Distinguished Lecturer, the Convenor of the CIGRE (International Council of Large Electric Systems) C6/C2.34 Working Group on Flexibility Provision from Distributed Energy Resources, holds the 2017 veski innovation fellowship for his work on urban-scale virtual power plants, and is a recipient of the international Newton Prize 2018 for his work on power system resilience in Chile. He is author of several books and over 300 research papers and reports, and is a journal editor of the *IEEE Transactions on Power Systems*, the *IEEE Transactions on Smart Grid*, and *Oxford Open Energy*. In recent years, Pierluigi has supported the Finkel Review panel, the Australian Energy Market Operator, the Australian Energy Market Commission, and the Australian Energy Regulator on research and consultancy projects on power system security, reliability, and resilience, and has led and been involved in several projects via the Australian Renewable Energy Agency and Cooperative Research Centres.

Keynote: Operational challenges of high renewable dominated grids and some perspectives

Professor Tapan Saha

Professor, Leader of Power, Energy & Control Engineering, Leader of UQ Solar, Leader of UQ Industry 4.0 Energy TestLab, University of Queensland

When a power system is dominated by variable renewable energy generators (e.g. solar and wind) to meet CO_2 reduction targets, fossil fuel based synchronous machines are expected to be retired from the network. The high penetration of renewables and the removal of synchronous machines imposes some challenges of maintaining the adequate level of system strength and inertia. Synchronous condensers, battery storage and pumped hydro storage are capable of strengthening the power system security against credible contingencies. This presentation will cover some of our recent research findings and will also provide a general perspective.

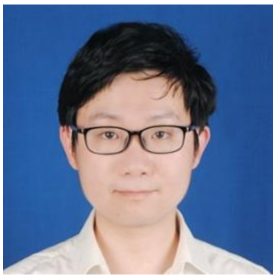
Professor Tapan Saha has been a Professor of Electrical Engineering since 2005 at the University of Queensland, where he joined as a Lecturer in 1996. He has been leading a research group of 60+ academics, post-doctoral research fellows and PhD students in power systems. He is a fellow of IEEE and Engineers Australia. He has successfully supervised 52 PhD and 11 MPhil students to their completions. He has published more than 600 technical papers in peer reviewed journals and conferences. He works very closely with the Australian Electricity Supply industry. He has received numerous awards, which incudes ALTC citation, MA Sargent award and ACPE -CIGRE Outstanding Academic Award for outstanding career-long contributions to teaching and research in electric power engineering as well as contribution to industry and CIGRE activities.

The role of hydrogen in decarbonising a coupled energy system

Mr Yimin Zhang

PhD candidate, University of Melbourne

The work presented examines the decarbonization of three coupled energy sectors: electricity, transport and heating/industry. The sector coupling includes the production of hydrogen from each of electricity via electrolysis, the gasification of coal and the reforming of natural gas; the displacement of gasoline/diesel and natural gas by any of these forms of hydrogen; the generation of electricity by gas turbines and reciprocating engines fuelled by either natural gas or any of these forms of hydrogen; and the electrification of the transport fleet. Plausible sensitivities to technological learning, energy efficiency measures, natural gas prices and subsidies for renewables are examined systematically as the coupled system's total greenhouse gas emissions are reduced to zero. The observed transition to zero emissions finds significant uses for hydrogen from both electrolysis and fossil fuels with carbon capture and storage (CCS). Plausible rates of technological learning from today to 2050 dramatically reduce the total costs and the land area required for achieving deep abatement mainly due to the projected fall in the costs of wind, solar PV and electrolysis. The combination of hydrogen fuelled reciprocating engines, electrolysis and hydrogen gas storage is also observed to provide lower cost, long term electricity storage than batteries and pumped hydropower. Nonetheless, the marginal costs of reducing emissions beyond approximately 90 % abatement relative to today are always more than 100 \$/t-CO_2 and land use can increase dramatically. This suggests that negative emission technologies will likely have a role in achieving net-zero emissions in combination with widespread renewable deployment, technological learning and some continued fossil fuel use with CCS.



Mr Yimin Zhang is a PhD candidate at the University of Melbourne. He holds a Bachelor of Energy & Environment Systems Engineering from Zhejiang University and a Master of Energy System from the University of Melbourne.

Thermo-mechanical energy storage options to decarbonise the Australian energy system

Dr Andrea Vecchi

Research Fellow – Clean Energy and Clean Transport, Mechanical Engineering, University of Melbourne

Long-duration storage with over 10 h capacity will be instrumental to cost-effectively satisfy demand when generation from renewables exceeds the 40/50% share. This presentation addresses the potential of thermo-mechanical storage technologies (where electricity is stored through conversion between thermal and mechanical energy) to meet the techno-economic requirements identified for long-duration storage. Thermodynamic models of six, between established and novel thermo-mechanical storage concepts were used to compare them on the basis of selected techno-economic performance indicators. A sensitivity analysis on model parameters was also carried out to highlight the potential effects of technological development. Finally, technologies are benchmarked against the energy storage requirements emerging from the Net Zero Australia project. Results significance is twofold: first, the present and future competitiveness of several thermo-mechanical energy storage concepts for long-duration storage is assessed; second, these concepts are confronted with the target techno-economic performance required to support Australia's decarbonisation.

Dr Andrea Vecchi received his MSc degree in Energy and Nuclear Engineering from Politecnico di Torino in 2016. He has spent 6 months as visiting student at Technical University of Denmark (DTU), during his last year of MSc. After a brief industrial experience, he undertook a joint PhD project between University of Birmingham and the University of Melbourne, on thermo-mechanical energy storage. He is currently working as a research fellow at the School of Mechanical Engineering, focusing on energy system modelling and decarbonisation.

Facilitating DER Services using Operating Envelopes

Dr Michael Liu

Research Fellow – Smart Grids, University of Melbourne

The proliferation of residential Distributed Energy Resources (DERs), such as photovoltaic (PV) systems and batteries, creates many opportunities for their owners to provide services to the Australian Energy Market Operator (AEMO) through aggregators. As the volume of DER providing services increases, it is also important to ensure the integrity of our electricity distribution infrastructure (i.e., the poles and wires). However, the big barrier is that distribution companies cannot directly manage DER or aggregators. Therefore, novel solutions are needed to ensure every household in Australia can make the most of their DERs. This presentation will introduce the concept of operating envelopes (i.e., time-varying export or import limits calculated at the point of connection of households) and how it can help distribution companies to orchestrate the bidirectional flows from DERs while ensuring the integrity of their poles and wires. It will also discuss how operating envelopes is being trialled, as part of the $28-million ARENA-funded Project EDGE, by AusNet Services using algorithms developed by The University of Melbourne. Finally, it will share the key challenges and learnings from the first-of-its-kind trials in Project EDGE as well as outlining the future R&D directions required to make operating envelopes business-as-usual across Australia.

Dr Michael Liu is a Research Fellow in Smart Grids with the University of Melbourne. He is an expert in the modelling and analysis of three-phase electricity distribution networks, distributed energy resources (DER) coordination schemes and advanced optimisation techniques. His expertise has led to 24 peer-reviewed publications and 7 technical reports across industry projects. Michael holds a bachelor's degree in Electrical Engineering since 2012 and a PhD in Electrical Engineering since 2020, both from the University of Melbourne.

Feasibility of energy community projects in Victoria: towards capturing their whole system value

Ms Carmen Bas

PhD candidate, University of Melbourne

The transition to low-carbon systems in Australia has been energized by customers installing rooftop solar and battery systems in their own homes and business. These customers have changed the energy system landscape, effectively becoming active energy market participants seeking to have a central and active role in the energy system. To these customers, energy communities present an opportunity to associate with other market players to provide system-level and local services on a level-playing field with respect to conventional market participants. However, energy community projects face multifaceted challenges of technical, economic, commercial and regulatory nature. While promising, it is still unknown if energy communities are commercially feasible projects. A general techno-economic framework is developed to quantify the benefits energy communities can provide, which value streams can these communities access and inform the different stakeholders on the value energy communities can provide. In this presentation, the proposed framework will be the cornerstone to explore two flagship projects in Victoria that aim to build energy communities with distinct use cases. Power Melbourne that aims to create a network of community batteries in the City of Melbourne, and the microgrid feasibility study led by C4NET analysing the potential of microgrids in two rural towns.

Ms Carmen Bas received her undergraduate degree in 2016 and then carried out a MSc degree at the Polytechnic University of Valencia (Spain) when she was sponsored to participate in a research program with the University of Berkeley in 2018 and continued as a research visitor at the Lawrence Berkeley National Laboratory (California). After this, she joined the University of Melbourne as a Ph.D. candidate where her work is focused on techno-economic modelling of distribution systems subject to uncertainty addressing planning, operation and new distributed energy markets.

Energy Materials

Chair

Dr Christian Brandl

On behalf of Associate Professor Wallace Wong, Program Leader, Energy Systems, Melbourne Energy Institute

Dr Christian Brandl completed his PhD in Materials Science & Engineering at the École Polytechnique Fédérale de Lausanne EPFL and the Paul Scherrer Institute (Switzerland), followed by a post-doctorate in the Theoretical Division at the Los Alamos National Laboratory (USA). Prior his position at the University of Melbourne, he headed a research group "Computational Nanomechanics of Materials" at the Karlsruhe Institute of Technology (Germany).

His research focuses on predictive atomistic simulation approaches to enable rational materials design. With his expertise on defects (e.g. dislocations, interfaces) in materials, he investigates defect-dominated properties (i.e. strength, reliability, stability) in advanced engineering materials: ranging from metallic nanomaterials (i.e. nanocrystalline metals, nanoparticle, nanolaminates, nanowires), to refractory metals/high entropy alloys.

Keynote: Promising top cell candidates for Si-based tandem cells

Professor Xiaojing Hao

ARC Future Fellow, School of Photovoltaic and Renewable Energy Engineering, UNSW Sydney

The development of high-efficiency silicon (Si)-based tandem cells is a promising solution for further LCOE reduction. To achieve a lower LCOE than Si cells, while with improved efficiency, the requirement for low degradation rate of Si tandems is critical, i.e. <2% degradation after the 1st year of operation and 0.5%/year afterwards. Despite the reported progress on the high bandgap top cells such as perovskite, there is no affirmed ideal top cell solution yet, meeting all the requirements of stability, cost-effectiveness, high-efficiency, and ideally environmental friendliness. Increasing the diversity of viable high bandgap photovoltaic materials is critical to maximize the chance of success in a reasonable timeframe, and to allow greater adaptability as the technology continues to expand and develop not only for further increasing the efficiency but also fulfill various application areas for everywhere PV. In this talk, the promise, challenges, and our recent progress on high bandgap top cell alternatives will be discussed.

Dr Xiaojing Hao obtained her PhD in the School of Photovoltaic and Renewable Energy Engineering of UNSW in 2010, and is currently a Professor at UNSW. Dr Hao has focused her research on low-cost, high-efficiency thin film solar cells and tandem solar cells for fifteen years, researching on various energy materials, initially using Si, and then earth-abundant compound semiconductor materials such as chalcogenides for both solar photovoltaic and solar fuel applications. She now leads a strong group in the above areas, achieving a number of efficiency records on emerging thin film solar cells. She has published more than 170 peer-reviewed journal papers, including a number of publications in *Nature Energy*, with several awards for her research excellence. She was the recipient of Inaugural Australian Renewable Energy Agency Postdoc Fellow, previous ARC DECRA, inaugural Sciential Fellow at UNSW and now ARC Future Fellow. She was awarded a number of prestigious national prizes, including 2020 Prime Minister's Prizes for Science: Malcolm McIntosh Prize for Physical Scientist of the Year, and 2021 Australian Academy of Science Pawsey Medal.

The synergy of automated fabrication, testing and machine learning: Open access materials discovery platform

Dr Maciej Adam Surmiak

Platform Engineer, Research Fellow, Monash University

A new era of renewable energy requires a fast, automated, large-scale high-throughput materials discovery in order to transition fully to a net-zero economy. The infinite materials parameter space (composition, surrounding condition, fabrication technique etc) is hard to explore using old-fashioned, inaccurate manual research. Hence, screening this parameter space using a rapid combinatorial screening approach could drastically speed up the rate of discovery. We present a fully automated, high-throughput open-style fabrication and characterisation platform available for users within Australia for solar, catalysts, organic/inorganic materials and similar. This fully automated, commercially developed robotic platform is destined to serve the Australian research and industrial community beginning next year, and here we provide more insights.

Dr Maciej Adam Surmiak in 2021 graduated from Monash University in the Faculty of Engineering (Chemical and Biological Engineering) specialising in High-Throughput Perovskite Solar Cell Materials Discovery. Previously, in 2014 he achieved a master's degree in Mechanical Engineering and Machine Build with a focus on MEMS sensors for early vibor-acoustic fault detection and with a Bachelor of Engineering in Electronics and Telecommunications specialised in thin films using novel electron beam deposition techniques, both Master's and Bachelor's degrees were accomplished at the Department of Electronics, Microsystems and Photonics at Wroclaw University of Science and Technology. Currently, Dr Surmiak is focused on developing a multi-million dollar multidisciplinary research platform (Australian Centre for Advanced Photovoltaics) together with specialists from Monash University, Exciton Science, CSIRO, NREL and a Swiss robotics company Chemspeed. Dr Surmiak also consults on modern and innovative solutions used at hybrid renewable energy systems including wind, battery systems, solar farms and more.

New strategies in sustainable molecular assembly with flow chemistry and catalysis

Dr Anastasios Polyzos

Senior Lecturer, Flow Chemistry and Catalysis, Chemistry, University of Melbourne

Recent advances in chemical synthesis are driven by the need for new tools which improve the efficiency of chemical synthesis and manufacture. Within this context, continuous flow chemistry has led to recognizable innovations in synthetic chemistry and continues to play a vital role in the discovery of novel reactivity. Furthermore, flow methods improve the efficiency and sustainability of chemical synthesis through deployment of low energy pathways mediated by innovations in catalysis. Recent advances from our group will be discussed in which flow chemistry, photochemistry and electrocatalysis are harnessed to deliver efficient and sustainable pathways for chemical manufacture.

Dr Anastasios Polyzos is a Senior Lecturer and ARC Future Fellow at the University of Melbourne, Australia. He holds a joint appointment with the CSIRO where his teams contribute to the development of new methods and enabling technologies for organic synthesis. Current research interests include new protocols for reaction discovery by harnessing highly reducing photoredox catalysis, C-H activation and flow chemistry. He currently serves as Director of the Australian Research Council Industrial Transformation Training Centre for Chemical Industries.

Cross-scale modelling of ion transport in nanoporous electrodes towards digital design of high-efficiency ionic devices

Dr Peiyao Wang

Research Fellow in Nanoionics, Chemical Engineering, University of Melbourne

Electrolyte ion-filled nanoporous electrodes are used in a wide range of energy storage and generation technologies such as batteries, supercapacitors and salinity gradient power. The performance of these devices is strongly affected by the transport of ions across different time and length scales and is dependent on many factors such as the ion mobility, the ion-electrode interactions, electrode geometry, and operational conditions. In particular, when confined in nanoporous electrodes, the electrolyte ions often exhibit anomalous physicochemical phenomena that are unattainable in the bulk counterparts. Modelling the complex ion transport processes across multiple scales is essential to realise the on-demand digital design of high-efficient and cost-effective ionic devices. Our group has been combining experiments, theoretical modelling and data science tools to design high-efficiency energy storage and conversion devices. This presentation will first give an overview of our research strategy and then present two case studies that are related to 1) molecular dynamics simulation of the solvent screening at carbon/electrolyte interfaces; 2) continuum modelling of spatiotemporal distribution of ions in nanoporous electrodes.

Dr Peiyao Wang is a research fellow in the Chemical Engineering Department at the University of Melbourne. Her research focuses on developing nanoscience-based models for nanoconfined dynamic ionic systems to enable the digitalisation of bulk nanoporous materials-based energy storage/generation devices.

Computational materials engineering for selective electrochemical CO_2 reduction

Dr Xing Zhi

The Australia's net zero roadmap for carbon neutrality by 2050 suggests a heavy reliance on clean energy technologies. There is a truly substantial requirement for energy storage of the intermittent renewables like solar and wind. The electrochemical CO_2 reduction reaction (CRR) using renewable electricity enables clean energy storage in chemical bonds by converting CO_2 into valuable chemicals and fuels. However, the complexity of reaction network in the CRR process leads to selectivity issues. Given this, development of efficient electrocatalysts is required to direct the CRR selectivity to a target product among competing reaction pathways. Computational modelling could greatly accelerate the electrocatalysts discovery process and facilitate the in-depth understanding of reaction mechanism for CRR pathway selection. This presentation will discuss the computational material engineering strategy for the development of efficient CRR electrocatalysts with improved selectivity toward a desired product. The efficient CO_2 conversion would benefit Australia to accelerate its pace in resource sustainability and to achieve carbon-neutral targets.

Dr Xing Zhi is a Research Fellow in the Department of Mechanical Engineering at the University of Melbourne. She has research interests in developing reaction mechanism understanding of electrochemical CO2 reduction and designing energy materials for converting CO2 into valuable products by computational method.

Power Generation and Transport

Chair

Professor Richard Sandberg

Program Leader, Power Generation and Transport, Melbourne Energy Institute

Professor Richard Sandberg is Chair of Computational Mechanics in the Department of Mechanical Engineering. His main interest is in high-fidelity simulation of turbulent flows and the associated noise generation in order to gain physical understanding of flow and noise mechanisms and to help assess and improve low-order models that can be employed in an industrial context.

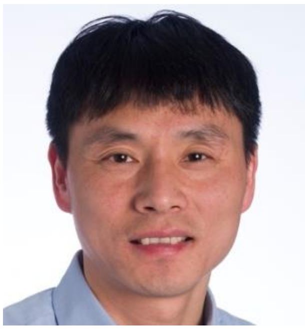
He has been awarded an Australian Research Council Future Fellowship (FT190100072) for 2020-2024 to continue developing his simulation and machine-learning capabilities to better understand and model turbulent flows and flow-generated noise. Prior to joining the University of Melbourne, he was a Professor of Fluid Dynamics and Aeroacoustics in the Aerodynamics and Flight Mechanics research group at the University of Southampton and headed the UK Turbulence Consortium (www.turbulence.ac.uk), coordinating the work packages for compressible flows and flow visualisations and databases.

Keynote: Carbon-neutral fuels for decarbonising combustion

Associate Professor Yi Yang

Mechanical Engineering, University of Melbourne

Achieving net-zero emission targets requires electrification of current combustion processes or, when this is not possible, replacing fossil fuels with carbon-neutral fuels produced from renewable resources. This talk will first review currently available options for carbon-neutral fuels and then focus on their application in combustion. A common topic in this area is the interactions between the green fuel and a second fuel co-burning in the combustion process. The second fuel is present either because of a gradual phase-in of renewable fuels to the conventional fuel mix, or because these renewable fuels do not burn properly by themselves. Given the large differences in physical properties and reaction chemistry, interactions between different fuels can be significant, which could largely impact the combustion performance. Several examples will be illustrated in this talk, including ethanol blends with gasoline, hydrogen blends with natural gas, and hydrogen enhanced ammonia combustion. These cases illustrate a rich area of research of which the outcome could enable additional dimension of optimization for clean, efficient combustion towards decarbonization.



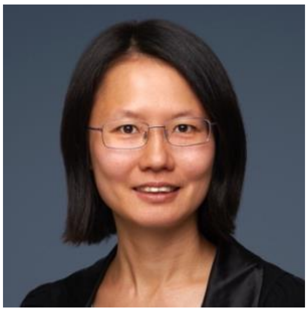
Yi Yang is an Associate Professor of Mechanical Engineering at the University of Melbourne. His research includes combustion chemistry, low emission fuels, advanced combustion engines, and fuel/engine interactions. He received his PhD from the Pennsylvania State University in 2008 and conducted postdoctoral research at Sandia National Laboratories before joining the University of Melbourne in 2012. He is an Associate Editor of the SAE International Journal of Engines and co-chaired the Engine Colloquium of the 38th International Symposium on Combustion. He is a member of the Combustion Institute and currently serves on the board of the Combustion Institute – Australia and New Zealand as the Section Secretary.

Rapid soil-structure interaction in sand for offshore energy applications

Dr Shiaohuey Chow

Senior Lecturer in Geotechnical Engineering, University of Melbourne

Rapid soil-structure interaction in saturated sand can occur in offshore energy applications such as drag anchor installation and touch-down of a jack-up unit's spudcan foundations. The rapid shearing in sand may result in extremely high resistance, introducing substantial risk (e.g. structural damage of jack-up unit) during placement of offshore facilities. This talk will present a centrifuge campaign involving different offshore applications (piezocone, spudcan and plate anchors) under rapid loading in sand. The centrifuge results indicated a 50% to 400% increase in soil resistance with increasing penetration velocity in dilating sand, which can be captured using a proposed backbone curve framework. The results also revealed complex pore pressure responses during rapid penetration in sand, with more insights provided through numerical studies.



Dr Shiaohuey Chow is a Senior Lecturer in Geotechnical Engineering at the University of Melbourne. Her research interests include offshore geotechnical site investigation using free-fall penetrometers, anchoring solution in sand and strain rate effects in soil. Her works have received several international best paper awards, including the Telford Premium Prize in 2016 and Manby Prize in 2014 from the Institution of Civil Engineers (ICE), UK. Shiaohuey is an Associate Editor for the Géotechnique Letters and International Journal of Physical Modelling in Geotechnics. She is also a member of the ISSMGE TC214 on Foundation Engineering for Difficult Soft Soil Conditions, and a committee member in the Australian Geomechanics Society (Victorian Chapter).

Air pollution from fossil fuels: A public health policy gap

Ms Clare Walter

Honorary Research Fellow in Biochemistry and Pharmacology, University of Melbourne

Burning fossil fuels is a major contributor to ambient (outdoor) air pollution – making it a key risk factor for acute and chronic health impacts, in addition to the long-term health implications of climate change. Until recently, the immediate health impacts have been overlooked and Australian policy has lagged in terms of preventative public health measures. Federal and related state air quality standards rely on international evidence for guidance, which may not accurately reflect the local context, and may also have contributed to the policy lag. There has been, however, a large increase in Australian epidemiological studies over recent years. An updated systematic literature review of peer-reviewed epidemiological studies was performed to reveal some of the short-term and long-term cardio-respiratory health impacts in Australia. In total, 72 studies were included in the review. Sixty-four studies (89%) used daily or hourly pollutant concentrations to examine short-term exposure impacts, of which 59 (92%) revealed significant associations with one or more health outcomes, including cardio-respiratory, all-cause mortality or morbidity, and birth outcomes. The evidence points to potential variances in the magnitude and range of health impacts and vulnerable groups that are contingent on the pollution source. The findings of this review highlight significant policy gaps. A case study using a recent major road project explores the implications of some of these policy gaps.

Ms Clare Walter originally trained as a clinical pharmacist specialised in oncology. Working in the lung clinics at Peter MacCallum Cancer Centre sparked an interest in air pollution. In 2014, Clare arranged the first Australian national meeting bringing together air quality academics and health professionals to discuss the impacts of air pollution and opportunities for advocacy in Australia. This initial meeting created momentum and Clare is now regularly involved in various advocacy initiatives engaging with affected communities, policy experts, government departments, health professionals, academics, and NGOs. She is currently undertaking a PhD examining the health impacts of air pollution and how Australian research may be positioned to achieve policy traction. Whilst the PhD is through the University of Queensland, Clare is based at Melbourne Climate Futures, here at the University of Melbourne where she holds an honorary position. Clare is the co-chair of the Health Special Interest Group at the Clean Air Society of Australia and New Zealand (CASANZ), a member of the Thoracic Society of Australia and New Zealand and the Public Health Association Australia. Peer reviewed publications include a review of the health impacts of air pollution in Australia and the siting of childcare centres near major roads in Melbourne.

The role of high-fidelity simulations in designing more efficient compressors

Mr Pawel Przytarski

Research Fellow, University of Melbourne

Flows in modern compressors are highly complex. They are subject to adverse pressure gradients, high levels of unsteadiness and often operate at transonic conditions. Such conditions render design tools based on low order methods unreliable which hinders further aero-engine efficiency improvements. These issues are further exacerbated by the current design trends towards more compact machines with higher work coefficients. To unlock further gains, researchers are employing high-fidelity techniques both in experiments and in computations. These techniques give unprecedented resolution and a wealth of data but extracting knowledge and distilling it into reduced-order models applicable to a wide range of flows is challenging, thus limiting their impact. This presentation discusses some of the challenges in compressor design and our recent efforts in harnessing high-fidelity datasets to inform industrial design and address some of the unknowns, specifically related to the various sources of unsteadiness and their interaction.

Mr Pawel Przytarski is a European Commission funded Maria Sklodowska-Curie research fellow working between Italy and Australia. As part of his project, he investigates how high-fidelity data can be used to shed light on multi-scale interactions within the turbomachinery flows. Previously he completed his PhD under a supervision of Andrew Wheeler at the University of Cambridge, Whittle Laboratory, where he used high fidelity simulations to study loss mechanisms in compressors.

High performance computation of hydrogen-fuelled engines

Dr Reza Yosri

Research Fellow in Clean Energy and Clean Transport, Mechanical Engineering, University of Melbourne

Renewable hydrogen has drawn attention in several countries as a potential alternative fuel for energy-producing devices like reciprocating engines. However, compared to conventional fuels like gasoline and diesel, hydrogen has different combustion characteristics and is more likely to experience abnormal combustion, such as knock. This talk aims to review our progress, particularly numerical simulation, in overcoming the technical difficulties of utilising hydrogen in reciprocating engines. The results of high-performance computations of a large bore, hydrogen-fuelled direct injection spark ignition (DISI) engine will be discussed where different spark and the start of injection (SOI) timings are used.

Dr Mohammadreza (Reza) Yosri is a post-doctoral research fellow in the Department of Mechanical Engineering at the University of Melbourne. He received his PhD from the University of Melbourne. Reza has a strong background in the fields of energy production, conversion and management and has worked with world-leading well-known researchers and companies. Reza's research includes numerical modelling and investigation of ultra-low emission reacting flows to design clean energy conversion devices.

Hydrogen and Clean Fuels

Chair

Associate Professor Kathryn Mumford

Program Leader, Hydrogen and Clean Fuels, Melbourne Energy Institute

Kathryn Mumford is an Associate Professor in the Department of Chemical Engineering at The University of Melbourne.

Kathryn's research interests are in the areas of separations processes, specifically ion exchange, solvent absorption, and solvent extraction technologies. These interests range from the manufacture of novel materials to the development of novel thermodynamic models to predict performance, and onto large-scale implementation in the mining, energy, environmental and wastewater processing fields. Kathryn currently teaches in the Master of Engineering (Chemical) program, namely Chemical Engineering Management and Heat and Mass Transport Processes subjects.

Keynote: Tailoring multifunctional catalysts for clean fuel synthesis

Professor Karen Wilson

Professor of Catalysis, Centre for Advanced Materials and Industrial Chemistry, RMIT University

Concerns over dwindling oil reserves, carbon dioxide emissions from fossil fuel sources and associated climate change are driving the urgent need for clean, renewable energy supplies. If average global temperature rises induced by greenhouse gases are not to exceed 1.5 °C, then estimates indicate that a large proportion of oil, gas and coal reserves must remain untouched. Biomass is nature's own incredibly successful solar conversion and energy storage system, and a versatile energy resource to produce heat and electricity on demand, or even be converted to liquid transport fuels and chemicals. Indeed, biomass, derived from agricultural and forestry residues, or non-food sources of triglycerides are a sustainable source of carbon that can provide low-cost solutions for transportation fuels and organic chemicals. Waste can become a key resource or feedstock, with the implementation of technology for waste valorisation in a circular economy estimated to have a potential economic benefit of $23 billion by 2025. Akin to petroleum refining, biorefining will integrate biomass conversion processes to produce fuels, power, and chemicals, thereby increasing the economic viability of bio-derived processes. Indeed, the US DoE identified a range of sugar derived 'Platform Chemicals' produced via chemical or biochemical transformation of lignocellulosic biomass that would be potential targets for production in biorefineries.

Catalytic technologies played a critical role in the economic development of both the petrochemical industry and modern society, underpinning 90% of chemical manufacturing processes and contributing to over 20% of all industrial products. In a post-petroleum era, catalysis will underpin biorefinery technology, and researchers will need to rise to the challenge of synthesising chemical intermediates and advanced functional materials and fuels from non-petroleum-based feedstocks. This presentation will discuss the challenges faced in the development of catalysts for biomass to energy processes and highlight recent successes in catalyst design which have been facilitated by advances in nanotechnology and careful tuning of catalyst formulation.

Karen Wilson was appointed as Professor of Catalysis in the School of Science at RMIT University in 2018, and was previously Chair of Catalysis and Research Director of the European Bioenergy Research Institute at Aston University (2013-17), where she also held a prestigious Royal Society Industry Fellowship in collaboration with Johnson Matthey. Karen holds a BA and PhD from the University of Cambridge, and MSc in heterogeneous catalysis from the University of Liverpool, and has held academic positions at the University of York and Cardiff University. She has published >280 peer-reviewed articles (h-index 74, 19,971 citations Google Scholar). Karen's research interests lie in the design the design of tuneable porous materials for sustainable biofuels and chemicals production from renewable resources. Recent projects have spanned the conversion of biomass from agriculture or forestry waste to fuels and chemicals, to the transformation of bakery waste to additives for application in coatings and polymers. She has also worked on depollution technologies to remove organic contaminants from wastewater in the seafood industry and palm and olive oil plantations in Southeast Asia. Karen is currently Associate Editor of Sustainable Energy & Fuels (Royal Society of Chemistry), and Energy & Environmental Materials (Wiley).

Use of water injection to control autoignition and knock in a heavy-duty, hydrogen-fuelled, reciprocating engine

Mr Joel Mortimer

PhD candidate, Mechanical Engineering, University of Melbourne

This talk presents a systematic study of a heavy-duty, DISI H2ICE for power generation. The engine was found to be knock-limited at fuel-rich conditions, in particular at higher compression ratios. In order to overcome this potentially destructive limitation, water injection was employed, enabling diesel-like powers at more optimal operating conditions to be achieved. Our further kinetic analyses shed light on the physics by which water injection extends the knock limits, allowing efficient operation of H2ICE at high powers.

Mr Joel Mortimer gained his undergraduate engineering qualifications at the Australian National University, before delving into eight years of experimental weapons propulsion and explosives research at DST Group. He describes making the green change to hydrogen research at the University of Melbourne as both challenging and rewarding.

Nitrogen and oxygen nucleation in cryogenic hydrogen mixtures

Dr Eirini Goudeli

Senior Lecturer, Chemical Engineering, University of Melbourne

Safe engineering design of industrial-scale storage and release of hydrogen demands a complete understanding of its thermodynamic properties at cryogenic conditions. Upon liquid hydrogen release, it mixes with ambient air, forming highly explosive, dangerous vapour clouds. However, the rate of nucleus formation in hydrogen-air mixtures is poorly understood and the equation of state of these mixtures remains unknown at cryogenic temperatures due to the lack of experimental data. Atomistic simulations can be utilised to reduce uncertainties in modelling of hydrogen plume during its release in ambient air. In this presentation, the homogeneous nucleation of nitrogen and oxygen at temperatures below 80K will be discussed. These calculations can provide information about the structure and energy of the liquid clusters formed during nucleation, which are challenging to be determined experimentally.

Dr Eirini Goudeli is a Senior Lecturer in the Department of Chemical Engineering at the University of Melbourne. Her research focuses on nanoparticle synthesis by flame spray pyrolysis, combustion, and hierarchical modelling of nanoparticle growth. Her research has been recognised by the bestowal of multiple awards, including the Inaugural Award for Outstanding PhD in Aerosol Science in 2018 from the Association of Aerosol Research and the 2020 Selby Research Award from the Selby Research Foundation.

Ultra-high-performance solar water splitting with earth-abundant cocatalyst foils

Dr Joshua Butson

Postdoctoral Research Fellow, Carbelec Project, Chemical Engineering,

University of Melbourne

Although solar water splitting efficiency continues to increase, stability and cost remain key issues. To improve the stability of immersed solar water splitting devices, earth-abundant cocatalysts were deposited on metal foil and then combined with high-efficiency photoabsorbers to construct fully decoupled photoelectrodes. The use of cocatalyst foils allows chemical-sensitive photoabsorbers to be removed from corrosive environments not only during device operation, but also during the synthesis of the earth-abundant cocatalysts, for which solution-based deposition techniques are often employed. This method was first applied to a GaAs artificial leaf, which maintained a solar-to-hydrogen (STH) efficiency of over 10% for longer than 9 days. Cocatalyst foils were then used to construct an immersed triple-junction device, achieving an excellent STH efficiency of 20.7% under 1 sun. This work paves the way towards immersed devices that are well-equipped to operate under concentrated illumination, further reducing material costs.

Dr Joshua Butson was born and raised in Perth, WA. He studied physics at Curtin University, graduating with a Bachelor of Science in 2014. He then undertook a PhD at the Australian National University, focusing on solar water splitting for green hydrogen. His postgraduate studies were completed in 2022. He is now a postdoctoral researcher at the University of Melbourne as part of the Carbelec project, which aims to convert CO_2 into solid carbon to reduce emissions from the steel industry.

A greener pathway to CO_2 capture

Dr Rebecca McQuillan

Research Fellow in Chemical Engineering, University of Melbourne

This presentation discusses potential methods of making CO_2 separation processes more sustainable. This includes catalytic solvent regeneration that can reduce the energy requirements associated with post-combustion CO_2 capture, and the application of direct air capture as an alternative approach to achieving CO_2 reduction.

Dr Rebecca McQuillan is a research fellow in the department of Chemical Engineering at the University of Melbourne. Her research background covers a multi-disciplinary range of project themes working to advance sustainable practices. Recent projects include the development of environmentally friendly fertilizer coatings, the remediation of contaminated soils in cold regions such as the Antarctic, and the analysis and modelling of CO_2 separation technologies.
