THE UNIVERSITY OF MELBOURNE

Melbourne Energy Institute

Symposium 2018

Presentation abstracts

Keynote and plenaries

Navigating the transition to the fourth revolution

Speaker: **Ms Audrey Zibelman** *CEO, Australian Energy Market Operator (AEMO)*

Abstract: Looking ahead, we as an industry are facing significant disruption and must look to capitalise on the opportunities presented in front of us. The pace of change is accelerating. Where the industry could once think about things in decades, we have to think about things in months. Adopting this forth industrial mindset, AEMO is focused on continuing to provide real value to our members and Australian energy consumers. By implementing a system of systems approach, the evolution of the energy ecosystem demands an evolution to the market system, and as the independent market and systems operator, AEMO is excited about the future.

Power system resilience and extreme weather events

Speaker: **Prof Pierluigi Mancarella** *Program Leader Energy Systems and Chair of Power System Engineering, The University of Melbourne*

Our understanding of classical reliability concepts is increasingly being challenged by: (a) growing shares of variable and partly unpredictable power converter-connected renewable energy sources; and (b) the more frequent occurrence of extreme events (for instance driven by climate change).

The aim of this talk is to discuss how, based on both technical and economic considerations, there is a need for introducing new modelling and quantitative assessment frameworks that are capable to securely deal with low-carbon power system operation and plan for future grids that are more resilient to high-impact, low-probability events.

The key question that will then be asked is whether the system should be made "stronger" (e.g., by hardening targeted components), "bigger" (e.g., making the system more redundant), or "smarter" (e.g., by introducing distributed technologies and advanced operational and control strategies).

Case study applications and results from a number of projects and real-world events from the UK, Chile and Australia will be used to practically exemplify the concepts presented.

The future of hydrogen in Australia: some thoughts

Speaker: **Prof Michael Brear** *Director, Melbourne Energy Institute, The University of Melbourne*

Abstract: Whilst hydrogen has been used as a fuel and industrial feedstock for the best part of a century, the prospects of the Hydrogen Economy have varied considerably over the decades. This has led some to say that 'hydrogen is the fuel of the future, and always will be'.

This seminar will consider whether the latest wave of interest in hydrogen has greater justification than previous waves, and what the key drivers of this interest might be. Do we have a good case for thinking that 'this time it's different'? If so, why?

Consumer response to road use prices

Speaker: **Dr Leslie Martin** *Senior Lecturer, Department of Economics, The University of Melbourne* (Co author Sam Thornton)

Abstract: We describe the results of a large road use pricing experiment that installed GPS responders in 1400 vehicles and implemented usage, time-of-day, and cordon charges via a system of virtual accounts. Using six-second location data collected over an eight to ten month period, we find a mean price elasticity of -0.11 to per kilometre charges, which is consistent with the literature on short-term demand response to fuel price increases. However constant charges, like petrol taxes, do not reduce congestion; they lead primarily to reductions in high-speed driving and off-peak road use.

We see no increase in driving to commuter rail and no reduction in commutes to work. We show that low-income drivers are the most responsive to road use charges and benefit the most from replacing existing transport taxes with fees that better reflect each driver's contribution to road use externalities.

Coal seam gas, conflicted communities and the promise of prosperity

Speaker: **Prof Fiona Haines** *Professor of Criminology in the School of Social and Political Sciences, The University of Melbourne*

Abstract: Coal seam gas promised to be a relatively trouble-free rich source of profits both for industry, for governments and local communities. Yet, it has proved divisive, generating significant protest against exploitation of the resource. This seminar explores the different dimensions of this conflict through analysing how a social licence to operate is understood by those involved in protest and counter protest. The analysis illustrates how feelings of identity and belonging shape how the technology is viewed together with its potential for benefit or harm. The resulting social conflict multiplies the challenges in generating an environmentally sustainable, socially just and economically viable future.

Energy Systems

National Electricity Market: Government interventions and the evolving political economy of the Australian power system

Speaker: **Dylan McConnell**
Supervisor: Prof Mike Sandiford

Abstract: It's often said that a week is a long time in politics. The two years since the 'black system' in South Australia and the resulting political response can respectively considered an eternity. During this period, we have seen some of the most significant developments and interventions in the National Electricity Market (NEM), since its inception almost 20 years ago. This includes (but is not limited to) Government led interventions, such as the South Australian Energy Plan, Snowy 2.0 and the ever-evolving National Energy Guarantee. Additionally, the Australian Energy Market Operator has also taken on a more proactive role with respect to planning and has shown a greater willingness to intervene in the operation of the market. This seminar will explore these interventions, the evolving political economy of the power system and the potential implications for the future and long-term sustainability of the National Electricity Market.

Financial performance of generators in energy-only markets with increasing variable renewables

Speaker: **Daniel Marshman**
Supervisor: Prof Michael Brear

Abstract: In power systems around the world, substantial quantities of variable renewables (wind or solar) are being introduced, often driven in part by policy such as a carbon price or a renewable portfolio standard. This changes the nature of power systems, as these generation resources are characterised by significant variability, uncertainty and low short-run costs. This can cause concerns for resource adequacy and revenue sufficiency as electricity prices can both decrease and become more variable. The financial performance of different generating technologies in an energy-only market with increasing wind or solar capacity is examined. In particular, the impact of unit commitment constraints on revenue sufficiency for thermal, renewable and storage technologies is assessed. The impact of a Rate of Change of Frequency constraint on generator financial performance is also presented.

Increasing PV hosting capacity in distribution networks: challenges and opportunities

Speaker: **Dr Andreas Procopiou**
Supervisor: Prof Nando Ochoa

Abstract: The cost reduction in residential-scale PV systems has led to the rapid adoption of PV systems in distribution networks. Whilst this is beneficial to the customers and environment, the resulting reverse power flows from multiple PV sites might lead to voltage rise and asset congestion issues, on both low-voltage (LV) and medium-voltage (MV) networks. Distribution Network Service Providers (DNSPs) in Australia and around the world have generally adopted two approaches to deal with these issues: time-consuming and expensive network solutions (i.e., reinforcing the existing network) or simply restricting additional PV system installations.

On the other hand, non-network solutions might provide fast, cost-effective alternatives. For instance, customer-owned controllable elements (i.e., PV and/or Battery Energy Storage (BES) systems) could be managed to mitigate technical issues. This presentation, based on projects with industry (i.e., EDF R&D, AusNet Services, EPRI), will first present challenges DNSPs are facing in evaluating the growing penetrations of PV systems in their networks and how computational simulation models and techniques can help overcome these. Then, novel non-network approaches that leverage existing network and customer-owned assets to mitigate technical issues will be presented. Lastly, an innovative control for residential-scale BES systems (patent being filed) that offers customers

energy self-sufficiency while mitigating network technical impacts will be presented.

Machine Learning Techniques for time series forecasting with application to smart grids

Speaker: **Ms Fateme Fahiman**
Supervisor: Prof Chris Leckie

Abstract: With an ever-growing population, global energy demand is predicted to keep increasing. Furthermore, with the integration of renewable energy sources (to reduce carbon emission and dependency on fossil fuels) and grid modernisation, the power system has become more volatile and less predictable than ever before. For example, renewable energy sources are weather dependent, which cannot be predicted exactly; we also need to cope with uncertainty in energy demand, consumer behaviour, energy prices, and transmission constraints. In fact, there are many sources of uncertainty associated with both demand and supply modelling. Thus, maintaining the balance between demand and supply at all times is a challenging task in the operation of electric power grids and also trying to produce more accurate load and renewable generation forecasting models has become a major research challenge for energy suppliers, energy marketers, financial markets, and other parties that contribute to electric power generation, distribution and transmission.

Historically, time series forecasting has mainly been studied in econometrics and statistics. In the last decade, machine learning, a field that is concerned with the development of algorithms that can automatically learn from data, has become one of the most active areas of predictive modelling research. This success is largely due to the superior performance of machine learning prediction algorithms in many different applications.

Frequency response constrained economic dispatch with consideration of generation contingency size

Speaker: **Sebastian Puschel**
Supervisor: Prof Pierluigi Mancarella

Abstract: Primary frequency response (PFR) requirements to stop frequency excursion after contingency are usually calculated on the basis of the potentially largest contingency, which is therefore a direct driver for frequency response adequacy. Future lower-inertia systems with larger volumes of non-synchronous renewables might require much higher levels of PFR to guarantee frequency adequacy; this might in turn significantly constrain system operation. Contingency size reduction could then

potentially lead to more efficient operation, and in extreme cases it might be necessary to find feasible operation points.

Hence, focusing on generation contingency, a novel mixed integer linear dispatch model is presented; it includes a set of hyperplanes that describe PFR requirements as a function of both system inertia and maximum contingency size (as a variable of the problem) to comply with predefine frequency response constraints such as rate of change of frequency (ROCOF) and frequency nadir. This allows efficient control of the contingency size in order to reduce operational costs and renewable curtailment associated to the need for additional inertia and/or spinning headroom to guarantee adequate frequency response. The proposed approach is demonstrated through applications on the Australian National Electricity Market, also including specifically developed frequency response security maps.

Environment and Energy Resources

Cities, transport, health and the climate transition

Speaker: **Professor Mark Stevenson**

Professor Mark Stevenson is an epidemiologist and Professor of Urban Transport and Public Health at the University of Melbourne. His appointment is across the Melbourne Schools of Design, Engineering and Population and Global Health. He is a National Health and Medical Research Council (Australia) Research Fellow, an Honorary Professor in the Peking University Health Science Centre, China and an advisor for injury to the Director General of the World Health Organisation.

Prof Stevenson has a PhD (Distinction) from The University of Western Australia and a Master's degree in Public Health from Curtin University and became a Fellow of the Australasian College of Road Safety in 2008. He has published over 220 peer-reviewed articles, books, book chapters and technical reports and procured more than $31 million in competitive research funding including funding from the NHMRC, ARC and the US National Institutes of Health.

Prof Stevenson has worked on numerous national and international projects that have directly influenced transport policy and worked with both Federal and State Governments in Australia and internationally. He has led many research groups and is internationally recognised in the field of transport safety and public health. Prof Stevenson is the director of the Transport, Health and Urban Design research hub comprising a cross-disciplinary research team exploring how the effects of urban form and transportation influence the health of residents in cities.

IPCC Special Report on 1.5 degrees warming: what does it mean for Australia?

Speaker: **Zebedee Nicholls**
Supervisor: Prof Malte Meinshausen

Abstract: The IPCC's Special Report, *Global Warming of 1.5°C*, provides a detailed investigation of the impacts of climate change in a world where we take strong, global, mitigation action.

In this talk, I will initially provide a broad overview of the report including its motivation, the process for compiling it and where all of the underlying data is stored. I will then briefly discuss my own area of expertise, carbon budgets and 1.5°C emissions pathways. This will offer an insight into the multiple lines of evidence which support the need for a drastic change to our economies, akin to a 'reverse industrial revolution', in order to limit climate change to manageable levels. Finally, I will put such a change in the Australian context, in particular highlighting the transitions that are required throughout our economy if we are to play our part in this global challenge.

Nitrogen oxides in Australia's urban environment: how clean is the air we breathe?

Speaker: **Rob Ryan**
Supervisor: Dr Robyn Schofield

Abstract: While Australia's overall air quality is typically perceived to be good by world standards, we owe this predominantly to our low population density. In fact, the combination of our reliance on road transport, coal-fired electricity and low regulation means Australia is the highest per capita emitter of nitrogen oxides (NOx) in the OECD. With city population densities booming, the risk posed by NOx and other air pollutants to the general public will continue to increase unless proactive measures are implemented. Scientists working to understand the wide-ranging impacts of air pollution are finding that reducing NOx could have substantial benefits for both the environment and human health.

This talk will highlight some of the sources, trends and health impacts associated with NOx in Australia, along with some personal and policy approaches to minimising pollution exposure.

Air quality and health: causal links specific to Victoria's environment

Speaker: **Sonya Fiddes**
Supervisor: Dr Robyn Schofield

Abstract: Air quality in Australia is among the best globally, yet still poses significant risk to the population. Currently, air quality in Australia is understood to have a total burden of disease of similar magnitude to that of sun exposure, with over 3000 premature deaths attributed to air pollution exposure in 2016. Unfortunately, air quality in Australia receives significantly less attention than other burdens of disease or causes of death. With Australia's growing population, especially in our cities, comes increased energy and transport demands, two major sources of anthropogenic air pollution. These trends provide further challenges to improving air quality in Australia, in addition to that of the threats placed on air quality by anthropogenic climate change, which includes greater risk of bushfire smoke exposure and dust pollution.

Currently, Australia's air quality monitoring is sparse and inconsistent across the country. While State based Environmental Protection Agencies are the main provider of information, as well as the main regulator of air pollution standards, they are limited in funding and mandate to provide Australia with the monitoring network needed. Australia's current network, as well as its air quality standards and regulations, lag considerably behind the international community, including the likes of California, China and Europe. Greater knowledge of Australia's air quality, air pollution events and trends are required to ensure a safe environment. This includes a monitoring network that is consistent across the country and operating at international standards. The provision of such a network would enable not only detailed, high resolution, in situ measurements of air quality, but also provides the possibility of better calibration to remote sensing instruments, such as satellites. Data such as these would be able to revolutionise the way Australians think about and respond to poor air quality events. The University of Melbourne is currently exploring such opportunities to create an internationally recognised network, and some examples of possible research outputs and instrumentation will be explored in this presentation.

Mineral precipitation from CO2 - saturated water in basalts and its potential for self-sealing of fractures and joints

Speaker: **Meghalim Phuken**
Supervisor: Prof Ralf Haese

Abstract: The permanent disposal of carbon dioxide in the subsurface has been considered a viable mitigation option to reduce global warming.

Sedimentary basins have been studied over years as a conventional storage reservoir for CO2 due to presence of caprock, but the mineralisation of CO2 might take thousands of years to occur. Continental flood basalts are considered unconventional CO2 storage reservoirs where interbedded massive basalt zones serve as barriers for upward CO2 migration.

However, vertical joints and subvertical fractures in those massive basalt zones may serve as conduits for buoyancy-driven CO2 migration and thereby pose a risk to CO2 containment. Basalts have high concentrations in Ca-, Mg- and Fe-bearing silica minerals and basaltic glass, which are known to dissolve in low pH, CO2-enriched water. The dissolution of basalt phases leads to an enrichment in dissolved silica and di-valent cations to the point when secondary minerals precipitate. This study determines whether mineral precipitation will seal joints and fractures during the vertical migration of CO2-enriched water and thereby contribute to CO2 containment. The interaction of CO2-saturated water with basalt wafers was studied in batch reactor at a pressure of 80 bars and 60°C for a period of 44 days. Si-Al-rich minerals and Mg- and Fe-oxides were observed as secondary mineral phases which could be potential sealants and mitigate CO2 leakage issue.

Reconfiguring energy, community and the region through the Copenhagen Climate Plan

Speaker: **Stephen Pollard**
Supervisor: Prof Fiona Haines

Abstract: "If everyone did as Copenhagen, the climate problem would be solved," asserts the City of Copenhagen's 2009 Climate Plan, a comprehensive vision for the city to stop contributing to the problem of global greenhouse gas emissions and furnish other cities in the world with solutions to do the same.

This paper examines Copenhagen's plan to become carbon neutral by 2025, and the conditions of possibility for the city to imagine and enact this vision. Drawing on four months of fieldwork conducted in Copenhagen in early 2018, it explores the contexts in which sociotechnical systems of energy, and relationships between the city and wider region, are reimagined and reconfigured through urban climate governance. In particular, the paper focuses on converting district heat and power plants from coal to biomass and waste-to-energy, and investing in new wind farms within and outside of the municipality. These examples reveal the complex social, technological and ecological factors that shape Copenhagen's approaches to reducing and counteracting emissions. Recognising sociotechnical change as contingent and relational reminds us that doing "as Copenhagen" will emerge differently in varied contexts.

Energy Technology

A new solar forecasting system to assist the energy transition in Australia

Speaker: **Dr Victor Depoorter Ruelle**
Supervisor: Prof Michael Brear

Abstract: As distributed and utility-scale solar photovoltaic (PV) rapidly grow in Australia, the operation and planning of the power system and electricity market needs to accommodate the variability and uncertainty of the solar resource. In this talk, a novel solar forecasting system combining several technologies to optimally forecast solar generation is presented. The system combines skycam cloud motion vectoring (CMV), satellite CMV, and numerical weather prediction (NWP). In the short-term, solar irradiance fluctuations are mostly due to clouds. Geostationary satellites taking high-resolution images of the Earth allow to identify, track and forecast the position of clouds to produce accurate forecasts up to 6 hours ahead. For utility scale generation, total-sky imagers provide information of local clouds structures with greater spatial and temporal resolution, increasing significantly the forecasting performance at short time scales. Finally, as new clouds form, change shape, or dissipate, NWP models become optimal when forecasting several hours or days ahead. While each technology provides benefits at different time scales, the optimal combination of these components can be used to reduce forecasting errors at all time-scale. This study will introduce the forecasting system, and analyse its integration in utility scale and distributed solar PV applications in the context of the National Electricity Market (NEM).

Turbine blade cooling prediction through high-fidelity simulations

Speaker: **Javier Otero**
Supervisor: Prof Richard Sandberg

Abstract: Our research is motivated by one of the current challenges of the turbomachinery industry, which consists of increasing the turbine entry temperature of the engines to increase thermodynamic efficiency and hence reduce fuel consumption. Consequently, this presents the complex challenge of designing the engine components that are exposed to these extreme temperatures, which must be able to endure such rough operating conditions. One of these critical components are the turbine blades, which need to be fitted with an internal cooling system which allows them to operate at temperatures beyond the melting point of the advanced metal alloys they are constructed of. Essentially, the cooling system bypasses lower temperature air from the compressor directly into the turbine blades. This cool air injection forms rows of cold jets which impinge onto a heated surface. Unfortunately, the flow physics of these setups are not fully understood yet, limiting the efficiency of the cooling

system design. Hence, our work consists of simulating this type of flows through high-fidelity methods, which will help us unveiling the dominant turbine cooling phenomena. A better understanding of these events will permit the design of more efficient gas turbines and reduce their fuel consumption.

Luminescent solar concentrator: from fluorophore synthesis to device fabrication

Speaker: **Bolong Zhang**
Supervisor: Prof Paul Mulvaney

Abstract: Luminescent solar concentrators (LSCs) are a type of light harvesting device that captures light from a large planar surface and concentrates the captured photons to a small area on the edge of the device (Figure 1). In comparison with traditional solar concentrators, LSCs can efficiently capture both direct and diffuse light and the device geometry allows for integration with buildings. Planar transparent and semi-transparent LSCs can be used as windows or as facades of buildings normally covered in glass. However, the application of LSCs is restricted by a number of performance issues including light harvesting efficiency, especially for large-area devices, and device stability and lifetime. Our research group has been focusing on:

1. The material development aspects of LSCs with special interest in designing new chromophore systems with high photoluminescence quantum yields in the solid state and with large Stokes shifts, including advanced organic small molecules and quantum dot-small molecule hybrid complexes.
2. The waveguiding system fabrication of LSCs in aspects of fluorophore selective alignment by liquid-crystal polymer matrix and large area device printing and casting skills.

In this presentation, I will introduce the principal of LSCs and briefly describe the researches we have done in the past three years and the current projects we are working with.

New singlet fission material for next generation organic photovoltaic

Speaker: **Sagher Masoomigodiarzi**
Supervisor: Dr David Jones

Abstract: The wide-scale deployment of OPV devices is possible by rapid reduction in the cost of OPV modules. Thermalisation losses cause a decrease in the efficiency of OPV devices. Several strategies to overcome thermalization

losses are being studied; one of them is carrier multiplication processes, such as multiple exciton generation and singlet exciton fission (SF). Singlet fission (SF) in which the absorption of one photon in an assembly of two nearby chromophores forms two triplet excitons from an excited singlet has attracted great attention in recent years as it has the potential to increase the maximum efficiency of solar cells from the Shockley-Queisser limit of 32% to nearly 45%. It can be observed under favourable energetics when the energy of the first singlet state (E(S1)) is at least twice that of the corresponding first triplet (2E(T1)). There are only a few reported SF materials and not all of them suitable for OPV device so it is important to design new SF chromophore. We designed new materials for SF based on conjugating strong donor and acceptor building blocks.

Technology innovation and the deployment of Carbon Capture and Storage (CCS)

Speaker: **Frank Wu**
Supervisor: Dr Kathryn Mumford

Abstract: As anthropogenic carbon dioxide (CO2) emissions continue to increase, global warming is drawing increased attention and concern across the world. This is particularly the case for countries and industries reliant on coal-fired power. In 2015 the Paris Agreement found that to limit temperature increases to below 1.5 °C, carbon capture and storage (CCS) needs to contribute a 13% reduction in CO2 emissions. Currently the deployment of CCS is facing some challenges due to primarily economic concerns, particularly due to its high energy requirement. The energy goes toward the regeneration of the capture solvents and injecting the captured CO2 underground, which compromises the profits of power companies. Therefore, it is essential to develop innovative technologies to reduce the energy consumption of CCS. This symposium discusses the state-of-the-art CO2 capture technologies and illustrates how the technology innovation can contribute to the reduction of energy costs and facilitate the deployment of CCS in the future.

Energy, Community and the Region

Corporate law driving clean energy transition? Litigation and carbon Risk

Speaker: **Dr Anita Foerster**
Supervisor: Prof Lee Godden, Prof Jacqui Peel

Abstract: This paper will profile recent research on the potential and limitations of corporate law tools (including risk disclosure obligations, fiduciary duties and shareholder resolutions) to influence decision-making by listed companies in ways which support clean energy transition. The underlying hypothesis is that obligations to identify and disclose the financial risks

posed by climate change and related duties to manage these risks to a corporation's interests can drive corporations to allocate capital and resources in ways which support transition away from carbon intensive energy. Experience in Australia, and comparative jurisdictions such as the United States and United Kingdom, suggests these tools have significant potential indirectly to influence corporate energy transition. There is considerable interest and momentum building among institutional investors and civil society to use these tools to ensure climate risks are fully disclosed and factored into investment decisions. Recent litigation on disclosure obligations and fiduciary duties, led by civil society and investors, is helping to crystallise these impacts, as are shareholder resolutions and other investor engagement initiatives with companies. However, without strong regulatory and market signals that create climate risks for business, the timeframes over which corporations recognise and act on climate risks are likely to be much longer than is required to support a swift transition to clean energy. Further, the focus on corporate performance and value and protecting the private interests of shareholders limits the extent to which these avenues can achieve public interest climate change mitigation and energy transition outcomes.

Prospects for distributed micro-grid electricity systems in India

Name: **Jonathan Balls**
Supervisor: Dr Sangeetha Chandra Sekeran

Abstract: This presentation focuses on prospects for a proliferation of micro-grid electricity systems in India, arguing that complex political and regulatory challenges will need addressing before they are likely to prosper. Thousands of small solar and biomass-based micro-grids have already been set-up, providing basic electricity to rural households without access to grid-based supply. The Government of India foresees the deployment of thousands more distributed systems in the coming years. Yet, a substantive role for micro-grids in India is far from certain. First, I will look at how while the delivery of electricity through the grid is mostly by government-owned companies and is centrally controlled, micro-grids are being set-up and operated by little-regulated private companies. Poor regulation of these businesses, and a lack of easy mechanisms for micro-grids to be inter-connected into the grid, is limiting their proliferation. Second, I lay-out how India has a long history of electricity being intricately entangled with politics, which has undermined the functioning of the sector. I argue that while micro-grid operators have avoided such politics so far, doing so will be difficult as they expand to serve more people.