THE UNIVERSITY OF MELBOURNE

MEI Symposium 21

Friday 3rd December 2021

Presentation abstracts and keynote speaker biographies

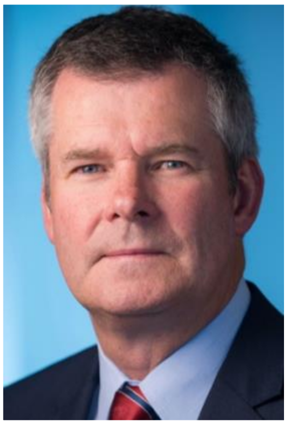
Melbourne Energy Institute

Contents

Plenary

Welcome

Professor Mark Hargreaves, *Pro Vice-Chancellor (Research Partnerships and Infrastructure),* The University of Melbourne



Mark Hargreaves is Professor of Physiology at the University of Melbourne, Australia. He has BSc (Physiology - 1982) and PhD (Physiology - 1989) degrees from the University of Melbourne and an MA (Exercise Physiology - 1984) from Ball State University (USA). He is a Fellow of the American College of Sports Medicine, of Exercise and Sports Science Australia and of the American Physiological Society.

As Pro Vice-Chancellor (Research Partnerships and Infrastructure) at Melbourne, he has oversight of the internal initiatives that foster interdisciplinary research, the important research relationships with external partners, and research infrastructure within the University.

His research and teaching interests focus on the physiological and metabolic responses to acute and chronic exercise, with an emphasis on carbohydrate metabolism and GLUT4 expression. He is a Consulting Editor for *Journal of Applied Physiology*, an Associate Editor for *Comprehensive Physiology* and serves on the editorial board of *Medicine and Science in Sports and Exercise*. He was a Board Director of the Victorian Institute of Sport 2004-2019 and currently serves on the Board of the Florey Institute of Neuroscience and Mental Health.

Chair

Professor Michael Brear, *Director, Melbourne Energy Institute,* The University of Melbourne

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.

Opening keynote

Ms. Anna Collyer, *Chair*, Australian Energy Market Commission

Anna Collyer is a leading energy expert and the Chair of the Australian Energy Market Commission. She has more than two decades of public and private sector experience in energy and has worked extensively on industry reform with energy ministers.

Anna has a passion for leadership and change and is a big believer in a learning culture, where experimentation is a necessary part of creating something new.

As a partner of Allens law firm from 2001 to 2020, Anna focused on the energy sector throughout its evolution, advised a broad range of clients in the public and private sectors on major projects, and fostered innovation at all levels of the firm, not only in technological developments but also in new ways of working and addressing disruption.

Anna has a Bachelor of Laws (Honours) and a Bachelor of Commerce from the University of Melbourne.

Energy Systems Research Program

STREAM 1 (AM)

Chair

Professor Pierluigi Mancarella, *Energy Systems Program Leader*, Melbourne Energy Institute, The University of Melbourne

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. Pierluigi obtained the PhD degree in Power Systems from the Politecnico di Torino, Italy, has been a Research Associate at Imperial College London, UK, and has held visiting research positions at Sintef/NTNU in Norway and NREL in Colorado, as well as visiting professorships at Ecole Centrale de Lille in France and the Universidad de Chile.

Pierluigi has been involved in/led, in the last 10 years, some 50 research projects and consultancy and professional activities in the UK, Australia, and internationally, in the area of techno-economics and business cases for smart grid technologies, risk and resilience assessment of future networks, integrated multi-energy systems modelling, and energy infrastructure investment under uncertainty. Pierluigi is the author of four books, several book chapters, and over 200 research papers. He is an Editor of the IEEE Transactions on Smart Grid, IEEE Systems Journal, International Journal of Electrical Power and Energy Systems, and Philosophical Transactions of the Royal Society A (guest). Pierluigi is also an IEEE Power and Energy Society Distinguished Lecturer and the past Chair of the Energy Working Group of the IEEE European Public Policy Initiative.

Keynote: Texas power grid under extreme weather in February 2021

In this presentation, Dr Ross Baldick discusses the effects on the electricity system in the Electric Reliability Council of Texas region of the extreme cold weather in February 2021. The weather context will be initially discussed, including its effect on electric demand, and on outages of generation in the lead up to and during the rolling blackouts. The reasons for the outages and blackouts will be explored, and the effect on wholesale prices will be explained. Broader implications for other regions will be suggested.

Dr Ross Baldick, *Professor Emeritus, Department of Electrical and Computer Engineering,* The University of Texas at Austin

Ross Baldick is Professor Emeritus in the Department of Electrical and Computer Engineering at The University of Texas at Austin. He has undergraduate degrees from the University of Sydney, Australia, and graduate degrees from the University of California, Berkeley. His current research involves optimisation, economic theory, and statistical analysis applied to electric power systems, particularly in the context of increased renewables and transmission. Dr Baldick is a Fellow of the IEEE and the recipient of the 2015 IEEE PES Outstanding Power Engineering Educator Award.

Extracting the physics of electrical networks using smart meter data: Towards model-free voltage calculations

Vincenzo Bassi, *Graduate Researcher,* Electrical and Electronic Engineering, The University of Melbourne

The widespread adoption of rooftop solar PV and electric vehicles can cause voltage rise or drop issues in the electrical networks connecting our homes. During operation, voltage calculations can help determining settings, such as PV curtailment, that ensure compliance with statutory limits. In planning, voltage calculations can help assess the effects of new connection requests. The main challenge for Distribution Network Service Providers (DNSPs), who manage the poles and wires, is that voltage calculations require power flow analyses (or similar) that need accurate electrical models. However, DNSPs struggle to have accurate and up-to-date electrical models of their low voltage (LV) networks connecting our houses. This talk will present an innovative approach to calculate voltages without electrical models (hence 'model free') using Neural Networks to capture the underlying relationships among the historical smart meter data and the LV network. The approach is part of the "Model-Free Operating Envelopes at NMI Level" project funded by the Centre for New Energy Technologies (C4NET) and is being tested with real smart meter data from multiple residential areas in Victoria. The initial results show a high level of accuracy, making it a promising alternative to DNSPs.

Electric vehicle charging preferences of Australian consumers

Dr Patricia Sauri Lavieri, *Lecturer in Transport Engineering*, Infrastructure Engineering, The University of Melbourne

Electric vehicles (EVs) have the potential to bring substantial economic and environmental benefits as they are less polluting and more efficient than most internal combustion vehicles. Large numbers of EVs, if appropriately integrated to electricity networks, may provide benefits to the grid through increased asset utilisation, demand management, and energy storage and redistribution. However, if unmanaged, EVs have the potential to increase peak demand leading to significant network and generation investment, and cause network security issues. This presentation will share recent results of a survey on preferences regarding EV charging of current and potential EV users in Australia. Insights into demand management will be discussed together with recommendations.

Integrated electricity-gas-hydrogen systems modelling with gas composition tracking

Isam Saedi, *Graduate Researcher,* Electrical and Electronic Engineering, The University of Melbourne

The electricity and gas systems are mainly coupled through gas-fired generators, electric compressors, and combined heat and power generators. An additional layer of coupling could be through power-to-gas units whereby energy from renewable sources can be converted to green hydrogen for injection into the existing natural gas system. However, injecting hydrogen into the natural gas system will lead to a noticeable deviation in gas properties, thus affecting the gas quality. This necessitates the development of an integrated electricity-gas-hydrogen systems (IEGHS) model that, on the one hand, can evaluate the renewable energy curtailments on the electricity system, and on the other hand, informs on the amount of hydrogen that can be injected and the changes in gas properties on the gas system. This talk will provide an overview of the IEGHS modelling, with case studies on real-world energy systems to highlight the importance of combined analysis of the electricity and gas networks in the presence of green hydrogen injections.

The role of energy storage on enhancing RES-dominated system reliability and resilience

Mr Guanchi Liu, *Graduate Researcher,* Electrical and Electronic Engineering, The University of Melbourne

There are many and far-reaching consequences of planning decisions towards a RES-dominated power system, most notably in terms of system reliability and resilience. When it comes to supply reliability and resilience, there is a vibrant interplay between RES, transmission networks, and storage in the context of RES integration and their enabling assets. As the penetration of RES keeps increasing, where large-scale wind and solar farm as well as roof-top PV have accounted for the majority of RES installation capacity, it will be critical to determine the role of different types of storage in supporting system reliability (as well as system resilience to extreme events) coordinating with RES at both transmission and distribution levels. A systematic framework is developed and presented for evaluating the contribution of RES and EES to the adequacy, flexibility, and resilience of RES-dominated system generation. The role of EES on enhancing RES-dominated system reliability and resilience is highlighted via real case studies. Further, the relationship between different types of EES investment and system reliability and resilience performance is clearly illustrated and explained.

Power Generation and Transport Research Program

STREAM 1 (PM)

Chair

Professor Richard Sandberg, *Program Leader Power Generation and Transport,* Melbourne Energy Institute, The University of Melbourne

Richard Sandberg is the 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: Wind power - five minutes into the future and beyond

The wind varies on a wide range of spatial and temporal scales, from turbulent eddies to seasonal and interannual scales. Wind variability on a multitude of scales impacts the predictability and volatility of the wind power resource. This presentation will discuss the operational and research impacts of a recent collaborative industry project aimed at improving wind power prediction 5 minutes into the future. The results will be discussed both in terms of the statistics of wind variability, the physical processes driving wind variability and the practical implications for wind power. Wind variability will also be discussed on several other key time-scales of relevance to wind power production.

Dr Claire Vincent, *Senior Lecturer in the School of Geography, Earth and Atmospheric Sciences,* The University of Melbourne

Dr Claire Vincent is a Senior Lecturer in the School of Geography, Earth and Atmospheric Sciences at the University of Melbourne. She has research interests in renewable energy meteorology, tropical variability and extreme weather.

Claire completed her PhD and a post-doc at the Technical University of Denmark between 2008 and 2014, where she discovered the drivers of extreme hour-scale wind variability at large offshore wind farms in the North and Baltic Seas. Claire commenced at the University of Melbourne in 2014, where she has worked on numerous collaborative projects relating to tropical variability, numerical weather simulations and very short-term wind power forecasting.

Aviation Impact Accelerator: Accelerating the path towards net-zero aviation

Dr Massimiliano Nardini, *Research Fellow in Aeroacoustics*, Mechanical Engineering, The University of Melbourne

The scope of the Cambridge Aviation Impact Accelerator (AIA) is to accelerate the path towards net-zero emission flights and towards a progressive decarbonisation of aviation by 2050. Sustainable Aviation Fuels (SAFs) represent an appealing alternative to current fossil fuels because they are compatible with current aircraft configurations and airport infrastructure. Producing sustainable fuels, however, poses several technological and infrastructural challenges, mostly related to the much larger amount of energy required with respect to current fuels.

An alternative solution towards zero carbon emissions is represented by hydrogen-propelled aircraft. Hydrogen can reduce the energy requirements compared to other types of fuels, but on the other hand it necessitates a whole infrastructure shift, from fuel production and distribution to substantial modifications to aircraft and airports. A third option towards greener aviation involves the adoption of electric propulsion, which can significantly drive down the energy requirements, at the expense of a reduced range of flight and cruise speed.

Given the scale of the problem, the technological and economic challenges, as well as the tight technical constraints associated with modern aviation, there is the need for scientific tools that offer a direct comparison between these different pathways. In this context, the AIA brings together the efforts of researchers from different disciplines to produce a model that allows us to simulate flights between different origins and destinations, with the aim of quickly comparing and optimising current and future aviation scenarios in terms of emissions, cost, technology requirements and overall flight experience. The model is designed to meet the needs of a broad range of users with different backgrounds, from scientists and industry leaders to investors and policy-makers, with the goal of guiding future technological, economical and political decisions, and unlocking and promoting new pathways towards sustainable aviation.

The electricity system benefits of improved wind generation forecasts

Dr Dominic Davis, *Research Fellow in Energy and Transport Systems*, Mechanical Engineering, The University of Melbourne

As the proportion of variable renewable generation capacity rises in our electricity systems, so too will the associated absolute forecast errors in their generation. Several studies around the world, including one undertaken at the University of Melbourne, suggest that once wind and solar exceed 30-40% of annual generation, their forecasts (in MW) become more uncertain than that of demand, with power system size and geographical diversity playing a role in this assessment. Importantly, these installed capacities are expected to be achieved in electricity systems, such as eastern Australia's National Electricity Market, in the next few years. This work examines the electricity system implications of increasing wind generation levels and corresponding increase in absolute generation forecast errors.

A stochastic unit commitment market model is used to simulate the decisions made by each generating unit in an electricity system, subject to their individual constraints including minimum output, minimum on time, minimum off time and start-up costs. These decisions are made under uncertainty – specifically, the forecast errors in demand, wind and solar generation. We then examine electricity systems with increasing penetrations of variable renewable generation and a series of wind forecast accuracy scenarios.

This presentation will highlight the potential financial and environmental benefits of improved wind forecasts to an electricity system, including impacts on wholesale market prices and costs; generator rates of return; system greenhouse gas emissions; and certain system reliability and security-related metrics.

Computational metallurgy for materials at extremes

Dr Christian Brandl, *Senior Lecturer,* Mechanical Engineering, The University of Melbourne

Advancements in technology are enabled by materials that allow safe and efficient performance. Applications range from turbines in airplanes and powerplants, to oil and gas pipelines, to more lightweight transport materials that allow the achievement of lower carbon emissions. Unfortunately, the reliable performance of alloys depends on particular aspects at the nano- to micrometre scale where failure starts.

Accelerating the materials innovation process requires truly predictive and computationally efficient modelling strategies appreciating the chemistry and the nanometre scale defect structure, which usually demand high-performance computing (HPC) infrastructure. Our modelling ansatz appreciated an industrial R&D context without dedicated HPC computing infrastructure, while the paradigm of truly predictive simulations without adjustable parameters is still applicable.

We combined dislocation theory and atomistic simulation to map out the different temperature regimes for the deformation behaviour of novel refractory high entropy alloys. Moreover, we demonstrate how to improve the simulation methodology to reduce computing time and resources significantly.

Recent trends in carbon geo-sequestration simulation studies in the machine learning era

Dr Achyut Mishra, *Sedimentologist (Geological CO*2 *Storage),* Geography, Earth and Atmospheric Sciences, The University of Melbourne

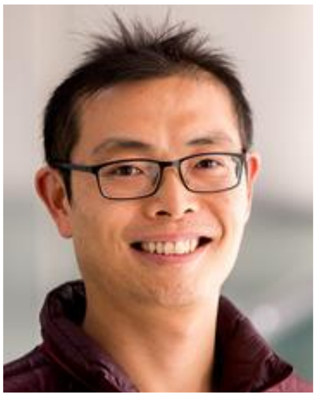
Geological storage of CO2 is an important strategy to reduce anthropogenic carbon emissions and meeting COP21 targets aimed at limiting global warming. The assessment of CO2 storage capacities of sub-surface reservoirs is traditionally done using complex multiphase fluid-flow and geochemical simulations. The recent developments in technologies for capturing high-resolution rock properties have paved the way for designing information-rich simulations. The results from these simulations are efficient at predicting the behaviour of CO2 under geological storage conditions as well as estimating the amount of CO2 that can be geologically stored in various reservoirs with high degree of confidence. However, these simulations also require immense computational resources. In certain scenarios, the enhanced amount of information makes it practically impossible to successfully execute the simulations. The recent developments in big data analytics and machine learning have paved the way for handling such large amounts of information and is a potential alternative to the traditional computationally intensive simulations. In this study, we present one such application of machine learning aimed at identifying regions within a reservoir where high CO2 storage capacities can be expected without the requirement of complex simulations.

Energy Materials Research Program

STREAM 2 (AM)

Chair

Dr Wallace Wong, *Program Leader Energy Materials,* Melbourne Energy Institute, The University of Melbourne



Wallace Wong is a Senior Lecturer in the School of Chemistry, the University of Melbourne, and leader of MEI's Energy Materials Research Program. He is a Chief Investigator and Research Theme leader in the ARC Centre of Excellence in Exciton Science.

Wallace has been an ARC Future Fellow (2014-2018) and an ARENA Research Fellow (2011-2014) and lead investigator on a number of organic solar cell projects including collaborative research programs with institutes in Germany and USA. The core expertise of this group is in the design and synthesis of organic materials with applications in light harvesting and solar energy conversion.

Keynote: High efficiency perovskite/silicon tandems for electricity and hydrogen

The world is now rapidly transitioning to renewable electricity. One of the key enablers of that transition is ultra-low-cost photovoltaics. High efficiency is an important factor that can contribute to achieving this target, making it easier to decarbonise the entire energy economy.

Combining perovskites with well-established photovoltaic materials such as silicon is an attractive approach for producing cheap, high efficiency and high voltage solar cells. Perovskite/silicon tandems have the potential for further progress in increasing the efficiency to 30% and beyond, and we discuss some of the key ways forward to achieving this goal. We demonstrate a 4-terminal tandem perovskite/silicon configuration in which the efficiency is as high as 27.7% through a passivation approach using 2D perovskites. We also demonstrate efficiency above 21% and fill factor of 83% for a 1cm2 single junction perovskite cell using a nanotextured electrode transport layer. The high efficiency achievable with perovskite/silicon tandems also enable high efficiency for direct solar-to-hydrogen generation, and we demonstrate a system that uses such tandems to achieve a solar-to-hydrogen efficiency of 20%.

Professor Kylie Catchpole, Professor in the School of Engineering, Australian National University

Kylie Catchpole is Professor in the School of Engineering at the Australian National University. She has research interests in solar cells and solar fuels as well as the broader energy transition. Her group has achieved leading efficiencies for perovskite and perovskite/silicon tandem solar cells, and their work on direct solar-to-hydrogen generation was listed as one of the top 10 innovations by the Innovation for a Cool Earth Forum (ICEF) in 2020. She was awarded the inaugural John Booker Medal for Engineering Science from the Australian Academy of Science.

Extending the lifetime of high temperature batteries for use in Venus landers

Dr Dean Glass, *Research Fellow in Battery Anodes,* Chemical Engineering, The University of Melbourne

Even though Venus is our closest planetary neighbour, little is known about it in comparison to other planets such as Mars. This is due to the harsh conditions on the surface (~465oC, 92 atm of pressure, H2SO4 in the atmosphere) which make surface exploration significantly difficult with the longest a lander has survived being two hours. Current lithium primary batteries are operational up to around 100oC and are not viable in the conditions mentioned to power a lander on Venus. High temperature batteries, which rely on molten salt electrolyte materials that are solid at room temperature and melt at elevated temperatures (>300oC), providing high conductivity and power, were investigated. A variety of cathode materials were tested for thermal stability and electrochemical activity at 475oC with ultra-low discharge rates (~C/720, C/1440, C/7200) as well as other various optimised cell components, designs, and operational parameters. Laboratory- and industrial-scale cells fabricated based on the optimised conditions displayed continuous operation (with and without pulsing) for over three weeks with the latter displaying cycling capabilities. This battery technology will help enable future long-duration surface missions on Venus.

Photochemical upconversion below silicon bandgap in oxygen mediated environment

Dr Elham Gholizadeh, *Research Fellow,* Ultrafast and Microspectroscopy Laboratories, School of Chemistry, The University of Melbourne

Improving the efficiency of silicon solar cells as the low cost and widespread kind of solar cells have attracted lots of attention. Triplet-triplet upconversion is one of the methods to increase this efficacy. However, most systems are working in visible region and are also sensitive to oxygen.

Last year, we could get closer to the final aim of using upconversion systems on solar cells by harnessing triplets below the silicon bandgap and suggesting a method to deal with oxygen problem of present photochemical upconcersion systems.

This presentation will discuss our approach to addressing these issues, as well as future steps.

Waste not, want not: how singlet fission can deliver cheaper power by minimising solar panel losses

Dr Calvin Lee, *ACAP Postdoctoral Fellow*, School of Chemistry, Bio21 Institute, The University of Melbourne

Crystalline silicon and other widespread photovoltaic technologies are currently hitting fundamental sunlight-to-power conversion efficiency limits. These limitations are imposed by the inability of current solar panels to effectively harness large regions of the solar spectrum, essentially wasting two-thirds of the available power. Research at the University of Melbourne is harnessing the ability of certain organic molecules to circumvent this wastage, by absorbing and converting 'unusable' high-energy light into wavelengths compatible with conventional photovoltaics – a process known as singlet fission. This has the ability to address extant problems in residential, utility and niche solar applications. Our next-generation materials improve upon the limited pool of singlet fission molecules, with a targeted approach towards integration with existing solar cell technologies.

Titanium oxide based carrier selective contacts for the next generation of crystalline silicon solar cells

Jesús Ibarra, *Graduate Researcher,* Electrical and Electronic Engineering, The University of Melbourne

Passivating contacts have emerged as the most promising alternative to deal with the fundamental limitations of direct metallisation on silicon. Titanium oxide (TiOx, x≈2) has been shown to be an effective passivating contact interlayer in a range of high efficiency crystalline silicon (c-Si) solar cells. It has been incorporated in a broad range of configurations; with and without passivating interlayers (i.e. silicon oxide SiOx, and amorphous silicon a-Si:H); with and without overlaying low work function electrodes (i.e. calcium, lithium fluoride / aluminium stacks LiF/Al); and in partial area and full area contact architectures, with efficiencies above 23% already demonstrated in the laboratory. With a bandgap bigger than 3 eV, parasitic absorption in TiOx is almost negligible when compared to e.g. doped a-Si and poly-Si films (the two most successful passivating contact approaches). Passivating contacts incorporating TiOx have enabled <10 fA/cm2 scale recombination currents and <10 mΩcm2 contact resistivities which are no inhibitor to cell efficiencies above 24%. Though most of the solar cell devices employ TiOx at the electron side, some studies have shown its potential tunability, which has enabled its use in hole contacts on c-Si as well, simply by varying film fabrication conditions and consequently changing its material properties. This talk explores the tunability of TiOx thin films and their incorporation into passivating contacts. Interface properties, thermal stability and remaining challenges for the incorporation of TiOx in industrial c-Si cells will be discussed.

Hydrogen and Clean Fuels Research Program

STREAM 2 (PM)

Chair

Associate Professor Kathryn Mumford, *Program Leader Hydrogen and Clean Fuels,* Melbourne Energy Institute, The University of Melbourne

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 waste water processing fields.

Kathryn currently teaches in the Masters of Engineering (Chemical) program, namely Chemical Engineering Management and Heat and Mass Transport Processes subjects.

Keynote: Electrochemical reduction of nitrogen

In current discussions of a path to a zero net carbon future, "green hydrogen" – producing hydrogen fuel using renewable energy – features prominently. The dream is capturing abundant but variable renewable resources – wind and sunshine – in a storable and transportable (and exportable) form. What does it involve? How can it be done? Is it feasible? How can it be used? Are there any other similar fuels? Ammonia? This talk will open up a discussion of the concepts, the issues and the possible solutions, including the production and use of ammonia as an energy carrier and fuel. In particular it will delve into recent progress on the Lithium mediated approach to N2 electroreduction to ammonia.

Professor Doug Macfarlane, *Sir John Monash Distinguished Professor,* School of Chemistry, Monash University

Doug MacFarlane is a Sir John Monash Distinguished Professor in the School of Chemistry, Monash University. Doug is head of the Energy Program in the ARC Centre of Excellence for Electromaterials Science. He is currently researching materials that will enable new pathways to generate energy and fuel from sustainable resources (e.g. the sun). One of his main focus areas within ACES is the generation of 'Green Ammonia' from nothing more than air, water and sunlight. He has published more than 800 papers and 30 patents, with more than 60,000 citations and h index 117).

His awards include the Australian Academy of Science Craig Medal, and the Victoria Prize for Science and Innovation. Doug is also the Founder and Chief Scientific Officer of Jupiter Ionics P/L, a company spun out recently with seed funding from local investors to scale up the green ammonia generation technology developed in his group.

Understanding hydrogen autoignition and knocking in spark-ignition IC engines

Dr. Farzad Poursadegh, *Postdoctoral Research Fellow,* Mechanical Engineering, The University of Melbourne

The use of hydrogen as an alternative fuel in internal combustion (IC) engines poses several challenges and opportunities. Whilst hydrogen's wide flammability limits and its carbon-free chemical structure provide an opportunity to achieve ultra-low, engine-out emissions, its propensity for abnormal combustion could give rise to serious operational challenges. This is particularly the case for engine operation under high power demands, where engine knock is more likely to occur. This work, therefore, investigates hydrogen combustion and its resistance to autoignition in a research spark-ignition (SI) engine. Our detailed measurements indicate that hydrogen has a higher knock resistance compared to standard gasolines. This finding has significant implications for designing highly efficient hydrogen-fuelled SI engines for power and propulsion.

Techno-economic analysis of membrane contactor systems for carbon capture

Dr Ehsan Soroodan Miandoab, *Graduate Researcher,* Chemical Engineering, The University of Melbourne

Over the coming years, carbon capture will play a significant role in achieving clean energy. However, an economically viable carbon capture technology has yet to be successfully commercialised. Chemical absorption with an appropriate solvent may be a potential candidate but energy penalties associated with this technology must be addressed. Gas-solvent membrane contactor systems exploits the benefits of two technologies, membranes and chemical absorption, and holds promise to reduce the required equipment area and energy penalties. In this work, a techno-economic analysis of membrane contactors systems is presented using a custom membrane contactor model which is developed in Aspen Custom Modeller (ACM) and interfaced with Aspen Plus. The techno-economic analysis is compared with that of chemical absorption at similar processing conditions to demonstrate the competitiveness of the membrane contactor technology for carbon capture. Hence, the outcome from this research is the transitioning of membrane contactor technology to commercial implementation.

Underground hydrogen storage: Advantages, challenges and opportunities

Dr Samintha Perera, *Lecturer in Geotechnical Engineering*, Infrastructure Engineering, The University of Melbourne

The time has come to replace fossil fuels with renewable energy sources to achieve Australia's net-zero atmospheric global carbon target. This has, however, been challenging due to the highly weather-dependent nature of our renewable energy sources, as solar and wind energy, resulting in often mismatches between the demand and supply. The efficient way of handling the mismatch is converting the extra energy into hydrogen and storing it until the demand comes. Australia is already amongst the global leaders in the green hydrogen industry, with several projects commencing soon and some pilot projects already underway. However, although the produced hydrogen can be stored using various methods as high-pressure gas cylinders, cryogenic tanks, long term storage of a large volume of hydrogen as an additional energy source has still been challenging. The only option is storing hydrogen in geological formations, depleted oil and gas reservoirs, aquifers, or salt caverns. An underground structure with high porosity and permeability, enabling large storage capacity and gas containment, impermeable cap rock-like structure to trap the gas and operating temperature not exceeding 135 ℃ and pressure up to 35 MPa makes an ideal candidate for UHS.

Among the various options, hydrogen storing in depleted gas reservoirs is an appealing option for Australia because of readily available many oil and gas fields (e.g. Bonaparte and Browse basins Carnarvon, North Perth and Perth basin, Otway, Bass, Torquay and Gippsland basins, Eromanga, Cooper, Bowen, Surat and Galilee basins from, Canning basin). However, underground storage has many issues that must be checked before confirming a site. The generally expected hazards are chemical reactivity of hydrogen gas with metal hydrides, dissolved solutes, microbial metabolisms, high leakage propensity due to the low viscosity, react with steel elements and diffuse through cement, causing wells' integrity issues. The time has now come to consider initiating some pilot tests in available depleted gas fields to obtain experiences and information for large-scale hydrogen storage capacity implementation in Australia.

Hydrogen utilisation through gallium based liquid metal alloys

Dr Ali Zavabeti, *McKenzie Fellow,* Chemical Engineering, The University of Melbourne

Crystalline silicon and other widespread photovoltaic technologies are currently hitting fundamental sunlight-to-power conversion efficiency limits. These limitations are imposed by the inability of current solar panels to effectively harness large regions of the solar spectrum, essentially wasting two-thirds of the available power. Research at the University of Melbourne is harnessing the ability of certain organic molecules to circumvent this wastage, by absorbing and converting 'unusable' high-energy light into wavelengths compatible with conventional photovoltaics – a process known as singlet fission. This has the ability to address extant problems in residential, utility and niche solar applications. Our next-generation materials improve upon the limited pool of singlet fission molecules, with a targeted approach towards integration with existing solar cell technologies.

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