



THE UNIVERSITY OF  
**MELBOURNE**

—  
**Melbourne  
Energy  
Institute**

# **MEI Symposium 19**

**Friday 13<sup>th</sup> December 2019**

**Basement, Melbourne School of Design**



# Welcome

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Welcome to the Melbourne Energy Institute's second Symposium, showcasing the University of Melbourne's multi-disciplinary energy research across four programs: **Energy Systems; Power Generation and Transport; Hydrogen and Clean Fuels;** and **Environment and Resources**.

The University's remarkable graduate students, research staff and guests will present on cutting edge energy research in these areas. Twenty-two topical seminars, including eight Keynote Speakers, will be held throughout one day across three theatres. Keynote speakers include:

## **Designing the next energy market**

**Dr. Kerry Schott AO**, Independent Chair, Energy Security Board

## **Unlocking Bottom-Up Services: From DER Integration to Orchestration**

**Prof. Nando Ochoa**, Professor of Smart Grids and Power Systems, University of Melbourne

## **Emerging issues in Energy Delivery**

**Prof. Gerard Ledwich**, Chair in Power Engineering Electrical Engineering and Computer Science, Queensland University of Technology

## **Resilient Energy Infrastructure: Risk and Legal Responses**

**Prof. Lee Godden**, Director, Centre for Resources Energy and Environmental Law, University of Melbourne

## **Air quality assessment and management**

**Dr. Andrea Hinwood**, Chief Environmental Scientist, EPA Victoria

## **Simulation and data-driven modelling to improve gas turbines**

**Prof. Richard Sandberg**, Leader, Power Generation and Transport Program, Melbourne Energy Institute, Professor of Mechanical Engineering, University of Melbourne

## **Clean Fuels from Hydrogen – a case study of Dimethyl Ether (DME)**

**Prof. Paul Webley**, Leader, Hydrogen and Clean Fuels Program, Melbourne Energy Institute, Professor of Chemical Engineering, University of Melbourne

## **Emerging electrochemical technologies for hydrogen and ammonia production**

**Dr. HyungKuk Ju**, Research Scientist, Electrochemical Energy Systems at CSIRO Energy

# Program

<b>Date:</b>	13 December 2019	<b>Time:</b>	8:00am to 5:00pm
<b>Venue:</b>	Basement, Melbourne School of Design, The University of Melbourne, Parkville Campus		
<b>Registration:</b>	<a href="https://energy.unimelb.edu.au/news-and-events/events/mei-symposium-2019">https://energy.unimelb.edu.au/news-and-events/events/mei-symposium-2019</a>		
<b>Cost:</b>	Entry is free	<b>Enquiries:</b>	<a href="mailto:mei-info@unimelb.edu.au">mei-info@unimelb.edu.au</a>

Registration		Location:	MSD Basement Foyer
7:30 – 8:00am	Registration and coffee		
Opening Keynote		Location:	MSD Basement Theatre B117
8:00 – 9:00am	<b>Dr. Kerry Schott AO</b> – Chair, Energy Security Board <b>Keynote:</b> Designing the next energy market		
Stream 1 (AM)	Energy Systems	Location:	Singapore Theatre
9:00 – 10:00am	<b>Prof. Nando Ochoa</b> – University of Melbourne <b>Keynote:</b> Unlocking Bottom-Up Services: From DER Integration to Orchestration		
10:00 – 10:30am	<b>Ms. Han Wang</b> – University of Melbourne Techno-economic analysis of multi-services provision from smart community energy systems		
10:30 – 11:00am	<b>Dr. Maria Vrakapolou</b> – University of Melbourne Dealing with renewable generation uncertainty in power system operation		
11:00 – 11:30am	<b>Dr. Sleiman Mhanna</b> – University of Melbourne Integrated Electricity-Gas-Hydrogen System Modelling for Future Fuel Scenario Analysis and Planning		
11:30 – 12:30pm	<b>Prof. Gerard Ledwich</b> – Queensland University of Technology <b>Keynote:</b> Emerging issues in Energy Delivery		
Stream 2 (AM)	Environment and Resources	Location:	Malaysian Theatre
9:00 – 10:00am	<b>Prof. Lee Godden</b> – University of Melbourne <b>Keynote:</b> Resilient Energy Infrastructure: Risk and Legal Responses		
10:00 – 10:30am	<b>Dr. Nilakshi Waidyatillake</b> – University of Melbourne The Impact of Particulate Matter (PM2.5 and PM10) on Premature Mortality		

10:30 – 11:00am	<b>Dr. Claire Vincent</b> – University of Melbourne The meteorology of rapid changes in the wind and sun		
11:00 – 11:30am	<b>Mr. Achyut Mishra</b> – University of Melbourne Improvements in the estimation of trapping capacities of CO2 storage reservoirs		
11:30 – 12:30pm	<b>Dr. Andrea Hinwood</b> – Chief Environmental Scientist, EPA Victoria <b>Keynote:</b> Air quality assessment and management		
<b>Lunch</b>		<b>Location:</b>	<b>MSD Basement Foyer</b>
12:30 – 1:30pm	<b>Lunch, poster exhibition and judging</b>		
<b>Stream 1 (PM)</b>	<b>Power Generation and Transport</b>	<b>Location:</b>	<b>Singapore Theatre</b>
1:30 – 2:30pm	<b>Prof. Richard Sandberg</b> – University of Melbourne <b>Keynote:</b> Simulation and data-driven modelling to improve gas turbines		
2:30 – 3:00pm	<b>Mr. Davy Brouzet</b> – University of Melbourne Numerical simulations of reacting flows: Impact of chemistry modelling on combustion noise		
3:00 – 3:30pm	<b>Ms. Morgan Li</b> – University of Melbourne Turbulent boundary layers evolving over a rough-to-smooth change in surface condition		
3:30 – 4:00pm	<b>Dr. David Jones</b> – University of Melbourne Emerging Solar Cell Technologies		
4:00 – 4:30pm	<b>Mr. Mostafa Naemi</b> – University of Melbourne A data driven, hierarchical approach to wind farm modelling		
4:30 – 5:00pm	<b>Dr. Kai Morganti</b> – Project Manager, Transport Workstream, The Oil and Gas Climate Initiative Opportunities to decarbonise the transport sector using low-carbon fuels		
<b>Stream 2 (PM)</b>	<b>Hydrogen and Clean Fuels</b>	<b>Location:</b>	<b>Malaysian Theatre</b>
1:30 – 2:30pm	<b>Prof. Paul Webley</b> – University of Melbourne <b>Keynote:</b> Clean Fuels from Hydrogen – a case study of Dimethyl Ether (DME)		
2:30 – 3:00pm	<b>Dr. Joshua Lacey</b> – University of Melbourne Clean combustion in hydrogen-fuelled, reciprocating engines		
3:00 – 3:30pm	<b>Dr. Ranjeet Singh</b> – University of Melbourne Hydrogenation of Carbon dioxide to fuel (Methanol) via catalysis		
3:30 – 4:00pm	<b>Dr. Pedro Orbaiz</b> – Partner at Logios and Associate Professor at Instituto Tecnológico De Buenos Aires H2 buses. ICE or Fuel cell?		
4:00 – 5:00	<b>Dr. HyungKuk Ju</b> – Research Scientist, Electrochemical Energy Systems, CSIRO Energy <b>Keynote:</b> Emerging electrochemical technologies for hydrogen and ammonia production		
<b>Close</b>			

# Titles and Abstracts

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## Opening Keynote

MSD Basement Theatre B117

### Opening Keynote: Designing the next energy market

Dr. Kerry Schott AO

*Chair, Energy Security Board*

This presentation will focus on the large amount of variable renewable generation entering the system and how to best integrate these generators. The progress that is being made will be noted; and where we need more work. A way forward is emerging but not without challenge.

## Energy Systems

Singapore Theatre

### Keynote: Unlocking Bottom-Up Services: From DER Integration to Orchestration

Prof. Nando Ochoa

*Professor of Smart Grids and Power Systems, University of Melbourne*

Distribution-connected technologies such as residential PV and battery systems, also known as Distributed Energy Resources (DER), have not only become common in Australia but, more and more, are also providing services to the system operator (AEMO). While distribution networks are currently capable of dealing with the resulting power flows, it might not be the case when these services become significant. This talk will discuss the technical challenges associated with the unsupervised and unrestricted provision of bottom-up services and will demonstrate the importance of adopting adequate frameworks that incorporate last-mile network constraints and fairness to effectively orchestrate DER.

### Techno-economic analysis of multi-services provision from smart community energy systems

Ms. Han Wang

*Ph.D. candidate in the Department of Electrical and Electronic Engineering, University of Melbourne*

The Australian energy system is experiencing a transition towards a low carbon future. At a neighbourhood level, the increasing penetration of distributed energy resources (DER) and large loads from electrification of heating and cooling have brought new challenges in power system operation, such as growing demand for frequency control ancillary services (FCAS) and greater distribution network strain. In response to these challenges, consumer-centric aggregation concepts have been proposed to effectively operate DER and exploit flexibility from multi-energy sectors to provide grid services. This presentation will showcase a techno-economic analysis of a smart community energy system participating in energy and FCAS markets and providing capacity and reliability services using the available resources within the community.



## Dealing with renewable generation uncertainty in power system operation

Dr. Maria Vrakapolou

*Lecturer, Power and Energy System Group, University of Melbourne*

Dealing with uncertainty of introduced by the continuing penetration of Renewable Energy Sources (RES) in a robust way may result in a very expensive operation. On the other hand, by using heuristically chosen scenario cases, solutions may not meet the required reliability levels of the system. This talk focuses on chance constrained Optimal Power Flow (OPF) reformulations and control designs that aim towards an optimal cost and reliability certificates. Certain components may provide power balancing reserves (e.g. generators, loads) and other only power flow control (e.g. HVDC lines). The overall framework offers a reliable solution in a probabilistic sense while decreasing the operating costs by taking advantage of the potential flexibility of the network.

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## Integrated Electricity-Gas-Hydrogen System Modelling for Future Fuel Scenario Analysis and Planning

Dr. Sleiman Mhanna

*Senior research fellow, Future Fuels CRC's Integrated Energy Systems project, University of Melbourne*

The growing reliance on gas-fired generators and the potential advent of clean fuels are prompting a paradigm shift towards jointly modelling electricity, gas and hydrogen systems (EGHS). Against this background, this work presents an integrated EGHS modelling tool aiming at striking a good trade-off between computational complexity and accuracy, to investigate a large number of scenarios for the planning and operation of Australia's low-carbon future. This tool will incorporate realistic integrated system operational constraints, include dynamic gas flow capabilities, assess the role of the gas network for energy system decarbonisation, and quantify the positive impact of clean fuels.

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## Keynote: Emerging issues in Energy Delivery

Prof. Gerard Ledwich

*Chair in Power Engineering Electrical Engineering and Computer Science, Queensland University of Technology*

The increase in renewables is making the coal fired power stations run less and become less profitable. This can give rise to early retirements that are not planned so an important issue is to match the reduction in coal power with a rise of storage supporting renewables. As more wind and solar farms are connected to the grid in weaker locations we need systems which synchronize better. In distribution we have issues in the overvoltage from PV and developing for batteries combined with overloading from Electric Vehicles. AEMC advocates a cost-reflective customer reward pricing-how do we achieve this?

Environment and Resources	Malaysian Theatre
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## Keynote: Resilient Energy Infrastructure: Risk and Legal Responses

Prof. Lee Godden

*Director, Centre for Resources Energy and Environmental Law, University of Melbourne*

More frequent extreme weather events have become a feature of the Australian environment. While storms, floods and bushfires are still labelled as disasters, their occurrence is no longer so unexpected as in the past. This presentation considers the impact of extreme weather events on the electricity system, infrastructure and its operation. It draws on class-action litigation in the Queensland water utility sector to examine the ramifications for the National Electricity Market in terms of its preparedness to deal with extreme weather events and the instigation of resilient infrastructure.

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## **The Impact of Particulate Matter (PM<sub>2.5</sub> and PM<sub>10</sub>) on Premature Mortality**

Dr. Nilakshi Waidyatillake

*Research Fellow, Centre for Epidemiology and Bio-statistics, University of Melbourne*

Globally, agencies are investigating the relationship between particulate matter and premature mortality. However, to date, there is no comprehensive systematic review on particulate matter and premature mortality. The aim of this presentation is to present findings of a systematic review and a meta-analysis conducted using Bayesian approach on the association between particulate matter and premature mortality globally. This statistical method allows us to interpret causation based on weight of evidence. Also, we are able to do more robust generalizations of results and conclusions compared to those of one study which increase the statistical power and reduce the publication bias that exist in individual studies.

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## **The meteorology of rapid changes in the wind and sun**

Dr. Claire Vincent

*Lecturer, Atmospheric Science, University of Melbourne*

Atmospheric variability occurs on a wide variety of time and space scales, from turbulence through to global-scale waves. On sub-hourly scales, this variability can result in large amplitude fluctuations in wind and solar production. In this talk, I will discuss the meteorological processes that can lead to rapid (sub-hourly) changes in the wind and solar resource, including topographic effects, thunderstorms and squall-lines, cold-air outbreaks and the land-sea breeze circulation.

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## **Improvements in the estimation of trapping capacities of CO<sub>2</sub> storage reservoirs**

Mr. Achyut Mishra

*Ph.D. Candidate, Peter Cook Centre for Carbon Capture and Storage Research, University of Melbourne*

Geological carbon storage is one effective way to limit the rise of atmospheric CO<sub>2</sub>. The technology has been demonstrated at sites which span several kilometres across. However, the associated processes are scale dependent. The studies addressing sub-surface CO<sub>2</sub> storage often neglect the cm-scale geological information while estimating the storage capacity of the site. This study explores how the inclusion of fine scale information improves our understanding of CO<sub>2</sub> migration and trapping mechanisms. Our results show that cm-scale variation in rock properties may lead to an underestimation of CO<sub>2</sub> trapping capacity by up to 30-40% in km-scale CO<sub>2</sub> storage reservoirs.

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## **Keynote: Air quality assessment and management**

Dr. Andrea Hinwood

*Chief Environmental Scientist, EPA Victoria*

Globally, air pollution continues to be one of the most significant environmental contributors to poor health. In Australia, it is estimated that around 1.3% of deaths are attributable to air pollution. Air pollution arises from motor vehicles, wood heaters, industrial and agricultural activities, biomass burning and a range of other natural and human activities. EPA Victoria has the role of assessing and monitoring air pollution in Victoria; and we work with partners to reduce air pollution and minimise health impacts. The current state of knowledge of air quality in Victoria will be presented along with the approaches EPA takes to assess, monitor and manage sources of air pollution.

**Keynote: Simulation and data-driven modeling to improve gas turbines**

Prof. Richard Sandberg

*Leader, Power Generation and Transport Program, Melbourne Energy Institute, Professor of Mechanical Engineering, University of Melbourne*

Computational Fluid Dynamics predictions are becoming increasingly important in the design of gas turbines because correlation-based methods are unable to further improve efficiency and laboratory experiments with the required fidelity are prohibitively expensive. In this presentation, it will be shown how highly accurate simulation data can be used in two ways: 1) helping designers make decisions based on new physical insight, 2) improving current design tools to be more accurate so that designers can reliably explore a larger parameter space. The latter is achieved with a novel and unique data driven approach, developed at the University of Melbourne.

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**Impact of chemistry modelling on combustion noise**

Mr Davy Brouzet

*Ph.D. Candidate, Department of Mechanical Engineering, University of Melbourne*

With the development of high-performance computing, numerical simulations are more and more used to predict thermoacoustic instabilities in lean, premixed gas turbines. Several studies showed that combustion noise plays a key role in initiating these instabilities. Achieving a better understanding of sound generation by premixed flames is therefore crucial for designing safer gas turbines. The present study investigated the impact of chemistry modelling on combustion noise, using high-fidelity Direct Numerical Simulations (DNSs) of turbulent premixed flames.

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**Turbulent boundary layers evolving over a rough-to-smooth change in surface condition**

Ms Morgan Li

*Ph.D. Candidate, Department of Mechanical Engineering, University of Melbourne*

In this study, we examine the effect of a streamwise heterogeneous roughness on the development of a turbulent boundary layer. This is a simplification of the biofouling roughness which is often found occurring in patches on ship hulls in maritime applications. Through a set of carefully obtained experimental data covering a wide parameter space, we examine the applicability of a simple theoretical model to capture the effect of such a change in surface condition on the local wall-shear stress, which eventually provides further insight into the estimation of the drag penalty.

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**Emerging Solar Cell Technologies**

Dr. David Jones

*Senior Research Associate, School of Chemistry, Bio21 Institute, University of Melbourne*

The emergence of new low-cost solar cell technologies, capable of being R2R printed or vacuum deposited, have provided new possibilities when compared to traditional silicon solar cells. We have been developing new advanced organic semiconductors for improved organic solar cells and improved perovskite solar cells. In addition, light manipulation may allow us to target enhanced efficiency for silicon solar cells, so called 3rd Generation solar cells. I will discuss these new emerging technologies.

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## **A data driven, hierarchical approach to wind farm modelling**

Mr. Mostafa Naemi

*Ph.D. Candidate, Department of Mechanical Engineering, University of Melbourne*

Studying the integration of a wind farm into a power system requires an understanding of the dynamics of the wind farm. The development of a full model of a wind farm with a large number of wind turbines is computationally expensive. To find the reduced number of turbines to simulate the power generation of the entire plant, spectral analysis is conducted on a large amount of measured data of a wind farm. This analysis indicates that the cross-correlation between turbines' power output can be related to the convective length scale in the incoming wind. This correlation can be accounted for in the development of a hierarchy of reduced order models of wind farms. For these reduced order models, there is an inherent trade-off between accuracy and complexity.

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## **Opportunities to decarbonise the transport sector using low-carbon fuels**

Dr. Kai Morganti

*Project Manager, Transport Workstream, The Oil and Gas Climate Initiative*

Transport is widely regarded as one of the most difficult sectors to decarbonise and represents the fastest growing source of GHG emissions in more than 40 countries. To address international climate efforts, a range of technologies and energy sources will be required to decarbonize the transport sector – from electrification, improved fuels and engine technology, through to sustainable biofuels, hydrogen and carbon recycling techniques – each deployed where it provides the greatest possible impact, and adapted to local needs and pace of change. This presentation will address some of these broader challenges and discuss the potential role of low carbon fuels in decarbonizing road, maritime and aviation transport.

### **Hydrogen and Clean Fuels**

### **Malaysian Theatre**

## **Keynote: Clean Fuels from Hydrogen – a case study of Dimethyl Ether (DME)**

Prof. Paul Webley

*Leader, Hydrogen and Clean Fuels Program, Melbourne Energy Institute, Professor of Chemical Engineering, University of Melbourne*

DME is a very attractive future fuel because of its clean burning properties, ease of use, and potential manufacture from renewable sources. In this talk we present our results from energy and exergy analysis of DME production. The highest energy efficiency of 54.0% is obtained for steam and CO<sub>2</sub> reforming plus heat integration. The furnace in the reforming section is the main contributor to the overall exergy destruction in the process. Utilization of CO<sub>2</sub> in the reforming process reduces the amount of CO<sub>2</sub> emitted to the atmosphere by 50% per 1 kmol DME produced.

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## **Clean combustion in hydrogen-fuelled, reciprocating engines**

Dr. Joshua Lacey

*Post-doctoral research fellow, Department of Mechanical Engineering, University of Melbourne*

While reciprocating engines are often viewed as low efficiency emitters of greenhouse gases, it is important to recognize that these devices are not limited to the use of high carbon intensity fuels, and that the introduction of clean, alternative fuels may open pathways to higher efficiency. Prior research has identified significant opportunities to operate hydrogen-fuelled, reciprocating engines with high fuel efficiency that is comparable to and even superior to that of fuel cells, but with a potentially lower cost and more robust power plant. Such engines are therefore an attractive solution to the decarbonisation of transport and power generation.

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## **Catalysis for conversion of CO<sub>2</sub> and hydrogen to methanol**

Dr. Ranjeet Singh

*Research Fellow, Clean Energy Group, Department of Chemical Engineering, University of Melbourne*

Mitigation of CO<sub>2</sub> emissions by converting it to valuable products such as methanol is being widely examined. Methanol production via hydrogenation has several advantages over conventional process as it results in significantly less byproducts and requires less energy in product purification. Our work aims at synthesizing, characterization and enhancing catalyst performance in both gas and liquid phase hydrogenation reactions. In our lab, we have prepared hybrid Cu-ZnO-ZrO<sub>2</sub>/hydrotalcite and achieved high methanol selectivity. Furthermore, we are also developing a bimetallic Nickel-Gallium alloy catalyst and testing its performance.

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## **H<sub>2</sub> buses. ICE or Fuel cell?**

Dr. Pedro Orbaiz

*Partner, Logios, Associate Professor, Instituto Tecnológico De Buenos Aires*

The presentation will give a brief description of the current emission outlook of cities, establishing the necessity to migrate from the use of private cars to public transport, to reduce the transport sectors GHG emissions, and at the same time improve the emission profile of the public transport fleet to reduce the impact on urban air quality. After this, an overview of the available technologies and their niche of application in achieving a zero-emission public transport bus fleet is presented. Finally, the technoeconomic and environmental performance of a hydrogen fuel cell bus is compared to that of hybrid internal combustion lean engine hydrogen bus. A technical, environmental and economic life cycle analysis of each bus platform is presented, with results showing that the hybrid H<sub>2</sub> internal combustion engine alternative is a considerably more cost-effective solution to reduce both toxic and GHG emissions.

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## **Keynote: Emerging electrochemical technologies for hydrogen and ammonia production**

Dr. HyungKuk Ju

*Research Scientist, Electrochemical Energy Systems, CSIRO Energy*

Australia has an abundance of renewable energy sources and the highest potential capacity factors in the world that can be utilised locally for power generation as well as exported overseas in the form of green energy storage/carrier media such as hydrogen and ammonia via electrochemical technologies. A number of innovative electrochemical technologies are under development to realise this potential. Some of the examples are chemical assisted co-electrolysis using liquid hydrocarbons to reduce the overall energy consumption and green ammonia synthesis from water and air as the only feedstock. Further if these electrochemical processes can be coupled with renewables, these technologies can provide net zero emission pathways for energy production and utilisation. This presentation will discuss the different technologies and routes being considered to produce renewable hydrogen/ammonia, and CSIRO's areas of focus and advancements in this space.

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## Thank you to our partners

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