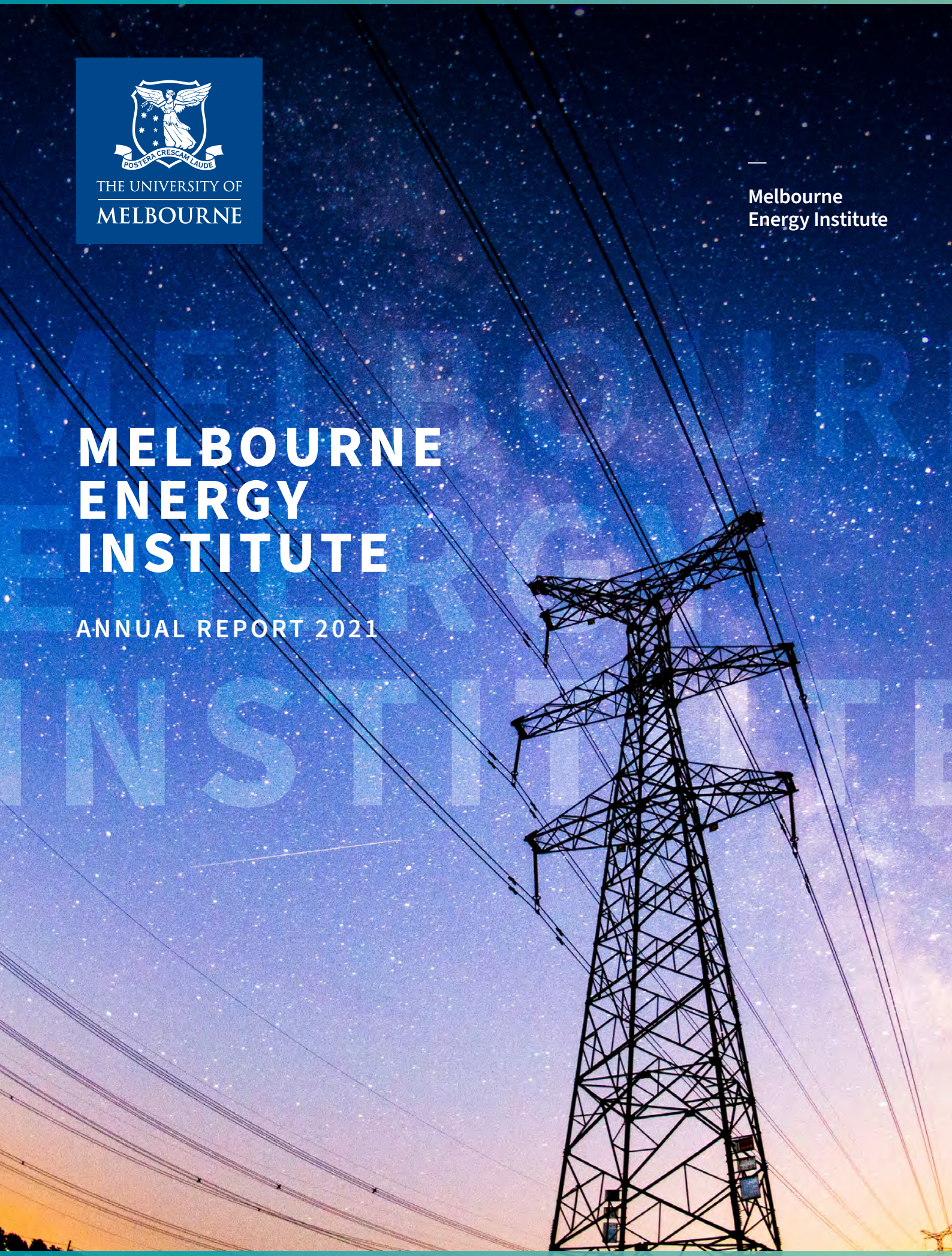
THE UNIVERSITY OF MELBOURNE

Melbourne Energy Institute

MELBOURNE ENERGY INSTITUTE

ANNUAL REPORT 2021



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MESSAGE FROM THE DIRECTOR

A second year of the Pandemic, and many of us were more exhausted at the end of 2021 than we were at the end of 2020. And for good reason.

But the MEI team kept at it.

Our MEI*network* seminar series returned to examine the entire electricity supply chain; from generation to the consumer; the old and the new. Our short course on energy investment decision making and MEI's hosting of AEMO's Quarterly Energy Dynamics seminars also continued. These initiatives were all delivered on-line, and we learnt what worked and what didn't, with strong attendance overall and a much wider reach to new audiences across the Nation and beyond.

We nonetheless all welcomed a *hybrid* MEI Symposium in December of 2021. Some real people in the same room, at long last! Talking to one another. Sometimes not agreeing but all of us learning. And having a nice cup of tea and a sandwich with someone you haven't seen for two years.

Our researchers were also most productive in terms of project delivery, publications and proposal writing. We are less sure about our collective performance on work/life balance. Or whether we all made it out of our pyjamas each morning before a long day in front of a screen.

Still, we celebrate some important research projects that progressed or commenced in 2021.

This includes *Project EDGE*, which is funded by the Australian Renewable Energy Agency (ARENA) and is an ongoing project between our partners AusNet Services, Mondo, the Australian Energy Market Operator (AEMO) and the University. This project is examining how Distributed Energy Resources can be accommodated whilst maintaining network security and maximising these resources' value to the consumer.

Melbourne Energy Institute also joined the *Aviation Impact Accelerator Initiative*; an initiative led by Cambridge University and supported by the World Economic Forum and others. Its main goal is to create an interactive, open-source, whole system model that can map the pathways and accelerate the journey to zero emission air travel.

And finally, MEI supported the successful application of the University's School of Population and Global Health to extend the *Tasmanian Longitudinal Health Study (TAHS)*. TAHS is the world's largest and longest-running study on respiratory health. It examines the impact of smoking, occupational pollutants and air pollution. The latter is particularly relevant to MEI as pollution sources include power generation, industry, vehicles and indoor fires.

I encourage you to read more about such initiatives in this Annual Report.

I also sincerely thank all my MEI colleagues and our wonderful partners from industry and government for their dedication and support over another, very complicated year.

All the best,

Michael

Prof. Michael Brear, FTSE, FCI, FIEAust
Director, Melbourne Energy Institute
March 24th, 2022

THE MELBOURNE ENERGY INSTITUTE

The Melbourne Energy Institute (MEI) delivers influential, interdisciplinary research on the transition to a clean energy system. We work with the community, industry and government on some of the world's most pressing energy challenges.

MEI has more than 300 specialists across Architecture, Economics, Engineering, Health, Law, Planning, Science and Social Science. They include a former Chief Scientist of Australia, several recipients of Australia Day Honours, several Fellows of Learned Academies and numerous Fellows of Professional Societies.

MEI researchers work together in four programs:

- Energy Systems
- Hydrogen and Clean Fuels
- Power Generation and Transport
- Energy Materials

We work with many leading organisations in Australia and overseas, and welcome all enquiries at mei-info@unimelb.edu.au.

INTRODUCING THE MEI TEAM

MEI is run by a team of dedicated staff who look after the Institute's external and internal research programs and stakeholder engagement.

Professor Michael Brear
FTSE, FCI, FIEAust
Director

Ms Anita La Rosa
Institute Manager

Catriona Croft-Cusworth
Communications and Events Coordinator

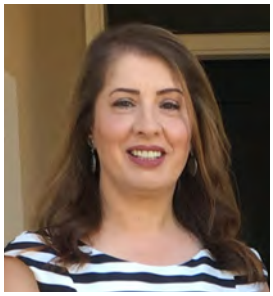
Professor Pierluigi Mancarella
Program Leader Energy Systems, and Chair Professor of Electrical Power Systems

Associate Professor Kathryn Mumford
Program Leader Hydrogen and Clean Fuels, and Associate Professor in the Department of Chemical Engineering

Dr Adrian Panow
Director Major Projects

Ms Monica Pater
Executive Assistant

Professor Richard Sandberg
Program Leader Power Generation and Transport, and Chair of Computational Mechanics



Ms Franca Tomaras
Administration and Events Assistant

Associate Professor Wallace Wong
Program Leader Energy Materials, and Senior Lecturer, Chemistry

MEI'S PARTNERS

MEI is proud to work alongside our industry and government partners. Collaborative research and knowledge transfer are central to MEI's work, and we welcome new partners.

HIGHLIGHTS OF 2021

LAUNCH OF NET ZERO AUSTRALIA: A GROUND-BREAKING STUDY

A two-year collaboration has begun to analyse how Australia can achieve a net zero economy by 2050. The Net Zero Australia (NZAu) project is a collaborative partnership between the University of Melbourne, the University of Queensland, Princeton University and management consultancy Nous Group. It is based on Princeton University's Net-Zero America study, which has attracted widespread interest from the United States government, businesses, non-governmental organisations and media (including the Economist and New York Times) since its release in late 2020. A notable feature of the Net-Zero America study was its highly detailed analysis of five distinct pathways to net-zero emissions by 2050. NZAu will undertake the same granular analysis of scenarios, which range from 100% renewable energy to one which includes significant carbon capture and storage. It will assess the progressive impacts of each scenario on emissions, infrastructure, costs, employment, land use, air pollution and other important outcomes at a high level of geographic resolution.

The project will also assess how Australia might export clean energy and low emission products, and thus contribute to the global decarbonisation task. The NZAu study will not recommend a preferred pathway or critique current policies; instead, it will present the costs and benefits of each scenario. Like the U.S. study, all methods, data and results will be made publicly available. NZAu is sponsored by APA Group, Dow, Future Energy Exports CRC, Future Fuels CRC, the Minderoo Foundation and Worley. The project is being overseen by a Steering Committee with nominees from the four participating organisations plus an independent member. An Advisory Group has also been established which includes nominees from the Australian Conservation Foundation, the Australian Council of Trade Unions, the Climate Council, Energy Consumers Australia, the Ethics Centre, the National Farmers, Federation, the National Native Title Council, St Vincent de Paul, three independent members, and nominees from each of the sponsoring organisations. The project will run until 2023 and will release interim findings throughout this period.

Read more

PROJECT EDGE: FACILITATING DER MARKET PARTICIPATION FROM THE EDGE OF THE GRID

Australia has the highest uptake of residential solar photovoltaic panels (PV) in the world. Battery storage systems are also becoming more attractive to Australian consumers. These and other *Distributed Energy Resources (DER)* are presenting new opportunities for owners to provide energy and other services to wholesale markets.

For example, aggregators can bundle DER to work as a single entity like a virtual power plant (VPP), allowing households to inject stored electrical energy from PV into the system in a more efficient way. However, as the volume of DER participating in such markets increases, it is becoming more necessary to ensure the integrity of the distribution network, guaranteeing that voltages and power flows remain within limits.

One challenge for distribution companies is that they are not permitted to directly manage DER or aggregators. Project EDGE (Energy Demand and Generation Exchange) is therefore demonstrating the use of so-called operating envelopes that are intended to better facilitate DER market participation from the 'edge' of the grid.

Rather than distribution companies giving households a fixed limit, such as the 5kW export limit per phase commonly used in Australia, distribution companies could use operating envelopes to calculate the most suitable local limits that ensure voltages and power flows are acceptable. These new local limits can be significantly larger than the fixed limits that are commonly used. This information can then be given to aggregators to decide how to best manage their DER portfolio. Furthermore, local market and pricing mechanisms can also be developed whereby network-related constraints and services will be priced in a consistent and integrated manner, i.e. co-optimised wholesale energy and ancillary services.

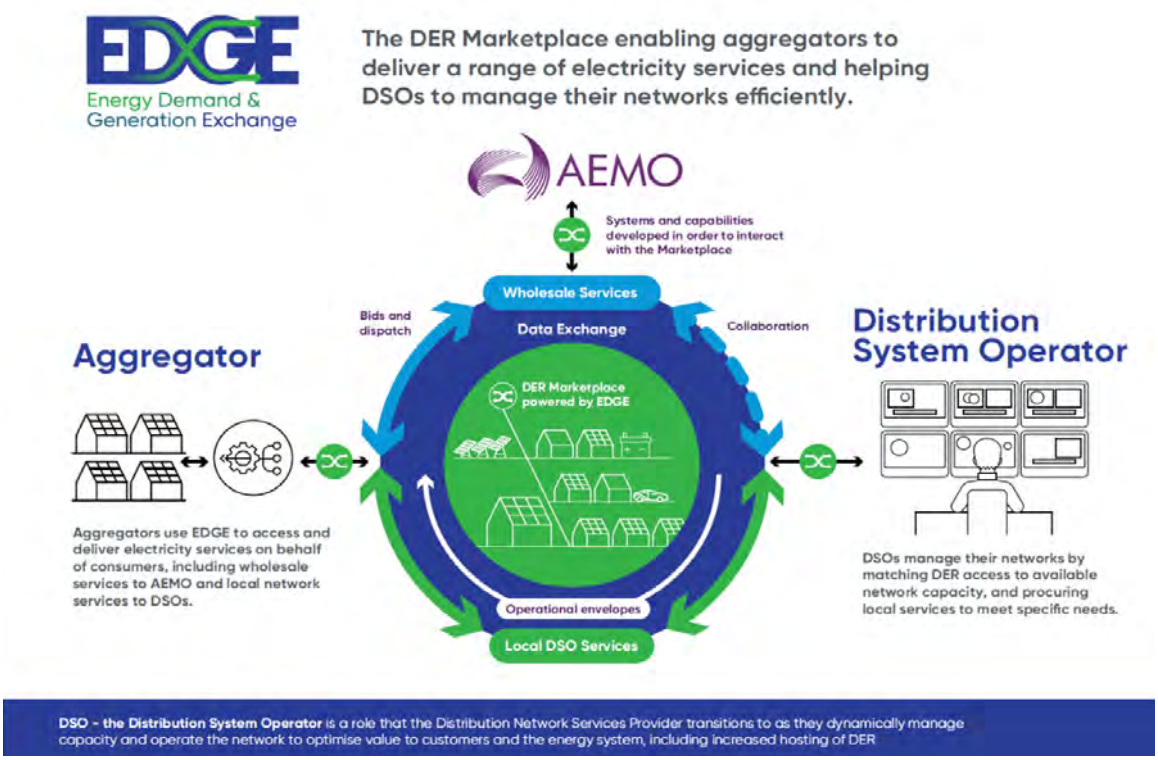
A key advantage of using operating envelopes is that it allows distribution companies to ensure network integrity without having direct control of the DER or the aggregator. This makes better use of existing infrastructure and increases the efficiency of the overall electricity value chain. Therefore, it should ultimately help to reduce electricity costs for consumers, particularly as we integrate more DER.

Project EDGE is a world-first project that brings together the spectrum of relevant stakeholders across the electricity value chain: customers, DER owners, aggregators, distributors, the system/market operator, and researchers. Several innovations will be demonstrated through trials that will test these operating envelopes and the trading of local services. This is crucial to understand the complexity, interactions and challenges that distribution companies will face globally as they accommodate the widespread adoption of DER. Project EDGE will also inform ongoing efforts on future electricity market design, particularly so-called two-sided markets.

Project EDGE was awarded funding by the Australian Renewable Energy Agency (ARENA), and is an ongoing project between partners AusNet Services, Mondo, the Australian Energy Market Operator (AEMO) and the University of Melbourne. Development of the algorithms for the operating envelopes and the service co-optimisation is being led by Professor Nando Ochoa and Professor Pierluigi Mancarella of the University's Department of Electrical and Electronic Engineering.

"AusNet is very pleased to be working with the University of Melbourne on Project EDGE. AusNet and the University have worked on several important projects over the last few years as our partnership has grown. The University's deep understanding of distribution networks, distributed energy resources and the orchestration of new forms of energy market will play a key role in delivering this project," said Mr John Theunissen, Director Smart Networks at AusNet Services.

Read more



THE MELBOURNE ENERGY INSTITUTE JOINS THE AVIATION IMPACT ACCELERATOR INITIATIVE

The Melbourne Energy Institute joins an international group of experts in aerospace, economics, policy, and climate science, who are building the Aviation Impact Accelerator, an interactive evidence-based simulator that allows you to explore scenarios for achieving net zero flight.

Aviation is one of the hardest sectors to decarbonise due to the very tight technical constraints. There are various options for replacing kerosene-powered flight, but all have their advantages and challenges. Sustainable aviation fuels, for example, do not require changes to current aircraft technology or infrastructure, but an immense amount of electricity is required for their production at scale. Hydrogen is another candidate but requires significant changes to aircraft and airport infrastructures. Electric propulsion requires the least amount of electricity, but also has the greatest constraints in terms of range. Thus, it is currently not obvious which technologies should be adopted and where investments are needed.

The Aviation Impact Accelerator (AIA) is an initiative led by Cambridge University, supported by the World Economic Forum, the Prince of Wales' Sustainable Markets Initiative, and others. Its main goal is to create an interactive, open-source, whole system model that can map the pathways and accelerate the journey to zero emission flight. By making the trade-offs of different choices visible, the model will help shape good decision-making; enabling increased confidence in delivery and scale up, guiding innovation and infrastructure development, and driving investment and policy action. Professor Richard Sandberg, Lead for MEI's Power Generation and Transport Program, Dr Massimiliano Nardini, a Research Fellow in Mechanical Engineering, and Professor Michael Brear, Director of the Melbourne Energy Institute, have joined the project's Systems Modelling Team that will integrate sub-models from the other sub-teams, namely the propulsion, fuel, airport, emissions and economic and policy teams, into a whole-system user interface.

Read more

CREATING CLEAN TRANSPORT FUELS FROM WASTE

For all of its bountiful produce, like meat, fish and crops, agriculture generates considerable waste. Of main concern is methane (CH_4), a gas burped by cows and released by rotting vegetation and manure, as it has a much higher global warming potential than carbon dioxide (CO_2). That is, methane in the Earth's atmosphere absorbs much more radiation energy per tonne of gas than CO_2, and so is a significant contributor to global warming. Furthermore, oxidation of methane in the atmosphere leads to the formation of ozone which is another potent greenhouse gas.

The transport sector currently accounts for approximately 20 percent of Australia's greenhouse gas emissions. Absolute transport sector emissions have increased by more than 60 percent since 1990 due largely to Australia's reliance on cars.

Australian road transport is currently dominated by vehicles that burn diesel and petrol. Although electric vehicles have bright prospects, it is unlikely that their use alone can meet our emissions reduction objectives, given the wide range of vehicles that we use (including heavy-duty trucks that are hard to electrify), Australia's vast distances and our low population density.

A paper by MEI Fellow Associate Professor Mohsen Talei, Dr Dominic Davis, and MEI Director Professor Michael Brear from the University of Melbourne, and Dr Davy Brouzet from Stanford University, is looking at ways to take the methane produced from agricultural and urban waste and using it as a cost-effective fuel in the transport sector – a fuel known as bio-compressed natural gas (bio-CNG).

Bio-CNG can be considered carbon neutral when combusted in an engine because the CO_2 emitted is offset by the CO_2 sequestered or 'locked up' in plant matter during its growth. Importantly, because bio-CNG can be generated from waste, precious cropland is not displaced to produce it.

Read more

EMISSIONS, AIR QUALITY AND THE ONGOING IMPACT ON RESPIRATORY HEALTH OVER THE DECADES

A research team led by Professor Shyamali Dharmage from the University's School of Population and Global Health has been awarded a $2.9m grant to extend the Tasmanian Longitudinal Health Study (TAHS). TAHS is the world's largest and longest-running study on respiratory health, spanning six decades and including seven follow-ups.

Research has shown that chronic obstructive pulmonary disorders (COPD) are major public health issues that become more common as people get older, particularly around 60 years of age. Globally, over 300 million people suffer from COPD, leading to 3 million deaths each year. In Australia, COPD is the third leading specific cause of total disease burden. This substantial and increasing global burden makes COPD a growing public health problem.

Environmental factors are a significant contributor to chronic obstructive pulmonary disorders. As explained by Professor Dharmage, "COPD includes smoking, occupational pollutants and air pollution caused by power generation, industry and vehicle emissions and indoor energy sources, particularly woodsmoke."

In 1968, the original TAHS study recruited 8,500 Tasmanian school children born in 1961. This cohort has been followed up six times, with the last follow-up occurring from 2012 to 2017 when they were 53 years old. This new follow-up study analyses this same cohort, now in their seventh decade of life.

The information collected in this study will be a valuable resource for research into COPD prevention and management. "The new study aims to understand the factors that cause the development and change in lung diseases over time, and develop risk prediction models to identify early who will develop COPD by 60 years of age. These findings will help us to better prevent and manage COPD", Professor Dharmage explains.

The TAHS has been based at the University of Melbourne since the early 1990s when Professor John Hopper and Professor Graham Giles followed up with the cohort when they were 32 years old. In 2001, Professor Hopper and Professor Giles handed over the leadership of the TAHS to Professor Dharmage. Subsequent studies of the cohort were carried in collaboration with Haydn Walters (University of Tasmania) and Michael Abramson (Monash University). This latest follow-up study will also feature collaboration with researchers from Harvard University and the University of Michigan.

To date, multiple PhD students, honours students and Master of Public Health students have completed their research within TAHS, with a further five PhD students now conducting their research within the program.

Read more

CREATING MORE SUSTAINABLE BATTERIES

The Super Anode Project is working on how to make much more sustainable graphite anodes for lithium-ion batteries, without sacrificing the performance and stability that make these anodes so great.

Lithium-ion batteries are everywhere. We now have far more electronic devices than people, each with a battery. We use them in our electricity networks. And we are increasingly using them in our cars. These batteries are, in principle, simple devices. They consist of an *anode*, an *electrolyte* that contains lithium, and a *cathode*. But there is an awful lot of science and innovation in each of these components, let alone how we put batteries together and use them.

Lithium-ion battery anodes are themselves a big business. Made from graphite, the performance of the anode helps determine the power and energy of a lithium-ion battery. The anode is particularly important because it's where the lithium ions are 'trapped' when the battery is charged. So how many ions the anode can hold, and how fast they can be stored or released, determines many of the battery's properties.

Graphite is cheap and abundant, and there is a wealth of knowledge of how we can process, functionalise and use it. While other materials such as tin and silicon can store more ions, none approach graphite's useful lifetime.

However, graphite anodes also have a rather big problem – they are usually made using environmentally unsustainable practices. Graphite is naturally occurring and mined but is also made from coal tar and pet coke, the leftovers of crude oil refining. A large amount of energy is required to make this synthetic graphite. Its manufacture is also a significant source of air pollution. Commercial anodes currently use a blend of natural and mostly synthetic graphite. With the booming lithium-ion battery industry, that can add up to a lot of emissions.

Natural graphite, in contrast, is a lot greener. There is therefore a big demand for natural graphite anodes that can match or even outperform blended or fully synthetic equivalents. Indeed, with our urgent need for much more renewable energy and the transition towards electric vehicles, it's critical that lithium-ion batteries be more sustainable.

Professor Amanda Ellis leads a research group in the University's Department of Chemical Engineering that is working on this challenge. Professor Ellis' team is taking mined natural graphite from our industry partners and developing pathways for processing and device assembly, while benchmarking anode performance against leading commercial anode materials.

This Super Anode Project is funded by the Future Battery Industries Co-operative Research Centre in partnership with CSIRO and the Queensland University of Technology. An impressive team of postdoctoral research fellows and graduate students is exploring many different aspects of natural graphite anode development. Over the next four years, the capability to produce high performance natural graphite anodes in Australia will be developed.

Read more

MELBOURNE ENERGY INSTITUTE RESEARCH PROGRAMS

ENERGY SYSTEMS

The Energy Systems Program considers how different energy technologies interact with one another, society and the environment. The program includes the technical, economic and environmental analysis of energy networks, wholesale and retail energy markets, and energy system planning.

CAPABILITIES

- Energy network, system and market integration of renewable energy sources
- Distributed energy resources and smart grids
- Integrated energy networks and multi-energy systems
- Security, reliability and resilience assessment of future energy systems
- Retail energy markets, consumer behaviour and demand modelling based on control trials, big data and machine learning

IMPACT

- Modelling work on future system security and energy markets commissioned by the Finkel Review
- AEMO demand and reserves forecasting using AMI data and machine learning approaches
- Modelling of electricity consumer behaviour for Billcap, Click Energy and Simply Energy
- Collaborations with AEMC and AER on power system resilience and reliability
- Integrated electricity-gas-hydrogen modelling for the Future Fuels CRC

RESEARCH CENTRES

- Centre for Market Design
- Centre for Resources, Energy and Environmental Law
- Power and Energy Systems
- Thermodynamics Laboratory

KEY RESEARCHERS

Program Leader: Professor Pierluigi Mancarella

Professor Lu Aye

Professor James Bailey

Professor Robin Batterham

Professor Howard Bondell

Professor Michael Brear

Professor David Byrne

Dr Sangeetha Chandra-Shekeran

Professor Robert Crawford

Professor Rob Evans

Professor John Freebairn

Professor Ross Garnaut

Professor Lee Godden

Professor Fiona Haines

Professor Glenn Hoetker

Associate Professor William Ho

Professor Chris Leckie

Professor Chris Manzie

Associate Professor Leslie Martin

Professor Brendon McNiven

Dr Reihana Mohideen

Professor Nando Ochoa Pizzali

Dr Behzad Rismanchi

Professor Mike Sandiford

Professor Prakash Singh

Professor Kate Smith-Miles

Professor Doreen Thomas

Dr Maria Vrakopoulou

HYDROGEN AND CLEAN FUELS

The Hydrogen and Clean Fuels Program integrates research into production, distribution and use of hydrogen in the energy system. The program studies electrolysis and clean fuel production, as well as hydrogen and clean fuel distribution and use in industrial and transport applications.

CAPABILITIES

- Process engineering and techno-economics of hydrogen production from renewables and fossil fuels with carbon capture and storage (CCS)
- Advanced gas turbine and reciprocating engine systems running on hydrogen and hydrogen-derived fuels
- Assessment of hydrogen integration into the natural gas network, including Power to Gas (P2G) concepts
- Catalysis and process engineering of converting hydrogen to clean liquid fuels
- Sub-surface storage of hydrogen
- Resource economics
- Resource Law

IMPACT

- Reciprocating engine research with hydrogen and synthesis gas fuelling for Caterpillar, Ford and other partners
- Support to the Council of Australian Government's (COAG) National Hydrogen Strategy
- Provision of expert advice to the Hydrogen Energy Supply Chain (HESC) Project
- Optimisation of integrated energy systems featuring hydrogen for the Future Fuels CRC and other partners

RESEARCH CENTRES

- Centre for Resources, Energy and Environmental Law
- Peter Cook Centre for CSS Research
- Thermodynamics Laboratory

KEY RESEARCHERS

Program Leader: Associate Professor Kathryn Mumford

Professor Robin Batterham

Dr Joe Berry

Professor Michael Brear

Professor Peter Cook

Professor Lee Godden

Dr Daniel Creedon

Dr Eirini Goudeli

Professor Ralf Haese

Professor David Jamieson

Professor Sandra Kentish

Dr Gang Li

Professor Pierluigi Mancarella

Professor Paul Mulvaney

Professor Richard Sandberg

Associate Professor Colin Scholes

Professor Geoff Stevens

Associate Professor Mohsen Talei

Associate Professor Yi Yang

POWER GENERATION AND TRANSPORT

The Power Generation and Transport Program brings together researchers who investigate several forms of renewable and low emission power plants for stationary and mobile applications. This includes advanced wind, solar, gas turbine, reciprocating engine and energy storage technologies.

CAPABILITIES

- Carbon Capture and Storage
- Conventional and alternative fuels and emissions chemistry
- Gas turbine, reciprocating engine, hybrid and electric powertrain dynamics and optimisation
- Wind turbines/farms, solar PV and energy storage dynamics and optimisation
- Low drag vehicles for land, sea and air
- Advanced computational methods and machine learning in energy applications
- Atmospheric chemistry
- Public health impacts of air pollution

IMPACT

- Propulsion, engines and fuels for Ford, DST Group and MHI
- Improved aircraft engine aerothermodynamics for General Electric
- Modelling of real-world, solar PV performance across Australia with AEMO
- Operational forecasting of wind and solar farm power generation with Meridian Energy Australia and others

RESEARCH CENTRES

- ARC Centre for Exciton Science
- Fluid Mechanics Group
- Peter Cook Centre for CSS Research
- Thermodynamics Laboratory

KEY RESEARCHERS

Program Leader: Professor Richard Sandberg

Professor Robin Batterham

Dr Graeme Beardsmore

Professor Michael Brear

Professor Mark Cassidy

Dr Shiao Huey Chow

Professor Peter Cook

Professor Shyamali Dharmage

Dr Robert Gordon

Dr Eirini Goudeli

Professor Ralf Haese

Professor Lloyd Hollenberg

Professor Sandra Kentish

Dr Patricia Lavieri

Professor Chris Manzie

Associate Professor Leslie Martin

Professor Stephan Matthai

Professor Jason Monty

Professor Paul Mulvaney

Professor Guillermo Narsilio

Professor Peter Rayner

Dr Behzad Rismanchi

Professor Mike Sandiford

Associate Professor Robyn Schofield

Professor Mark Stevenson

Associate Professor Mohsen Talei

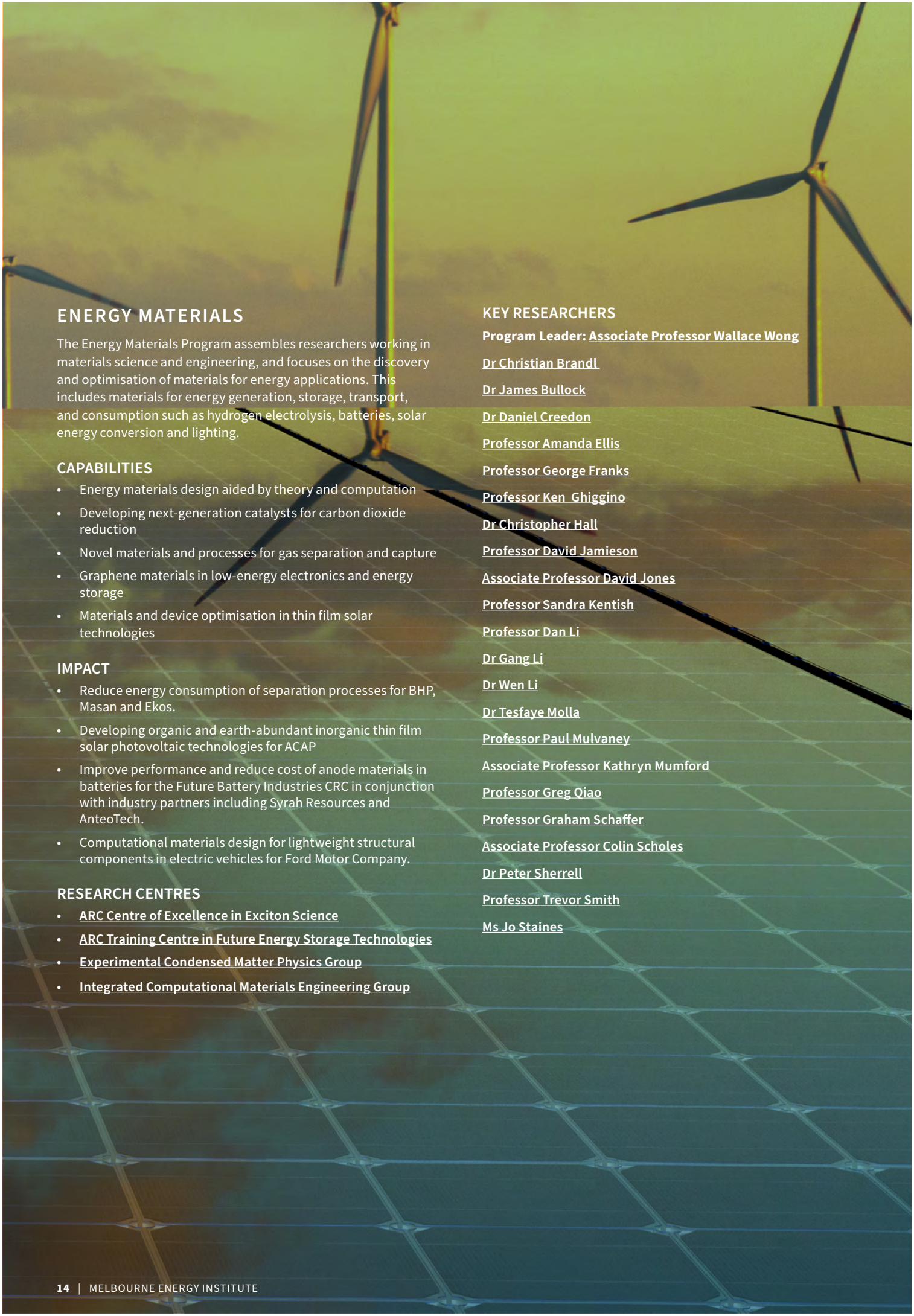
Associate Professor Yinghui Tian

Dr Claire Vincent

Professor Rachel Webster

Associate Professor Wallace Wong

Associate Professor Yi Yang



ENERGY MATERIALS

The Energy Materials Program assembles researchers working in materials science and engineering, and focuses on the discovery and optimisation of materials for energy applications. This includes materials for energy generation, storage, transport, and consumption such as hydrogen electrolysis, batteries, solar energy conversion and lighting.

CAPABILITIES

- Energy materials design aided by theory and computation
- Developing next-generation catalysts for carbon dioxide reduction
- Novel materials and processes for gas separation and capture
- Graphene materials in low-energy electronics and energy storage
- Materials and device optimisation in thin film solar technologies

IMPACT

- Reduce energy consumption of separation processes for BHP, Masan and Ekos.
- Developing organic and earth-abundant inorganic thin film solar photovoltaic technologies for ACAP
- Improve performance and reduce cost of anode materials in batteries for the Future Battery Industries CRC in conjunction with industry partners including Syrah Resources and AnteoTech.
- Computational materials design for lightweight structural components in electric vehicles for Ford Motor Company.

RESEARCH CENTRES

- ARC Centre of Excellence in Exciton Science
- ARC Training Centre in Future Energy Storage Technologies
- Experimental Condensed Matter Physics Group
- Integrated Computational Materials Engineering Group

KEY RESEARCHERS

Program Leader: Associate Professor Wallace Wong

Dr Christian Brandl

Dr James Bullock

Dr Daniel Creedon

Professor Amanda Ellis

Professor George Franks

Professor Ken Ghiggino

Dr Christopher Hall

Professor David Jamieson

Associate Professor David Jones

Professor Sandra Kentish

Professor Dan Li

Dr Gang Li

Dr Wen Li

Dr Tesfaye Molla

Professor Paul Mulvaney

Associate Professor Kathryn Mumford

Professor Greg Qiao

Professor Graham Schaffer

Associate Professor Colin Scholes

Dr Peter Sherrell

Professor Trevor Smith

Ms Jo Staines

STUDENTS OF MEI

Supporting early career researchers is central to MEI's growth. The Institute has a strong belief that in fostering the ambitious talent of early career researchers, we can help them become future thought leaders in the energy sector.

SPOTLIGHT ON A STUDENT

MEI has numerous graduate students working on important energy projects. Meet some of our talented students whose work is contributing to a more sustainable energy transition.

Through her PhD *'Energy efficiency in Australia's volume home building sector: investigating the influence of culture and practice'*, Erika Bartak aims to identify the opportunities for improved energy efficiency in mass produced housing.

Rahul Palulli's thesis, *'Direct numerical simulation of flame-wall interaction and flame-cooling air interaction'*, numerically investigates combustion under conditions relevant to natural gas-powered gas turbine power plants, with a special emphasis on CO emissions which limit the part-load operation limit of gas turbine engines.

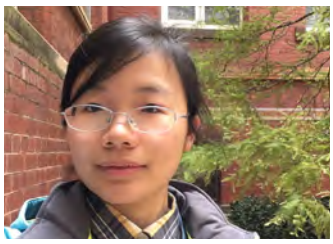
Katie Skillington is an architect and PhD candidate with the Melbourne School of Design. Her thesis examines the effects of design for dematerialisation (DfDm) on the environmental performance of multi-residential housing.

Mehdi Ghazavi Dozein chose his PhD research topic, *'Dynamic supports from converter-based resources in weak, low-inertia power systems'*, as it is aligns with his interests, skills and background. He has been working with, and researching, power system dynamics and operation for over 10 years, in both academia and industry. Mehdi is now an Assistant Lecturer in the Department of Electrical and Electronic Engineering.

Amanda Jayanetti is a PhD candidate in Computer Science and Information Systems. Her research focuses on harnessing the capabilities of Artificial Intelligence techniques for enhancing the energy-efficiency and performance of cloud and edge computing environments.

Saeid Charani Shandiz chose his PhD research topic, *'Towards resilient Net-Zero Emission Communities: A multi-dimensional approach for energy master planning,'* in response to identifying how emerging technological solutions can pave the way towards more sustainable designs and resolve global environmental issues.

James Helal is a Structural Engineer and a PhD candidate in the Melbourne School of Design at the University of Melbourne. His research focuses on developing a comprehensive framework that integrates embodied energy and greenhouse gas emissions into the structural design of tall buildings.



Xinbei Dou is a PhD candidate with the Department of Mechanical Engineering. Xinbei's PhD project aims to investigate the mechanism of hydrogen combustion under conditions relevant to real engine operation.

Milad Mohsenzadeh is a mechanical engineer at the University of Melbourne. Milad's PhD examines a novel form of solar-driven water desalination, a topic he is passionate about after researching the serious consequences of global warming on water security.

Edwin Chan is a PhD candidate in the Faculty of Business and Economics. His research explores consumer behaviour in the residential electricity sector, and how this is an important factor in reducing greenhouse gas emissions.

Yu (Cherry) Zhong is a PhD candidate in the Department of Infrastructure Engineering. Her research focuses on energy retaining walls, an innovative and economic form of Ground Source Heat Pump systems.

Isam Saedi is a PhD candidate in the Faculty of Engineering and IT. His research explores decarbonisation of the whole energy system using multi-energy-based models.

ENGAGEMENT

MEI runs a vibrant events and communications program that educates, informs and connects key stakeholders at the forefront of the clean energy transition. Our flagship **MEI*network*** program offers targeted educational and engagement opportunities for participants from academia and industry, while our **seminars, lectures and workshops** inform and stimulate broader collaboration and debate.

The shift to an online format for most events in 2020 and 2021, while lacking the advantages of in-person interaction, brought unexpected benefits for engagement, enabling participation by diverse stakeholders from academia, industry, government and community groups. We carried these lessons forward by safely hosting our year-end Symposium as a hybrid in-person and online event in December 2021.

MEI*network*21

The MEI*network* program provides opportunities for education, professional development and engagement among key research and industry stakeholders. Offered annually since 2018, it has become the centrepiece of MEI's events and engagement program.

The main components of the program are the **Energy Systems Short Course,** held mid-year as an intensive course for energy sector professionals and graduate students from the University of Melbourne; the **Energy Systems Seminar Series**, which offers a deep dive into the supply and value chain of a primary energy vector; and the **MEI Symposium**, which has become a platform for national and international researchers to share their latest findings on technologies, systems and opportunities for a clean energy transition.

The success of the MEI*network* program is made possible by the generous support of our industry and government partners. We work closely with our partners to develop a program that reflects current trends and challenges in the energy sector.

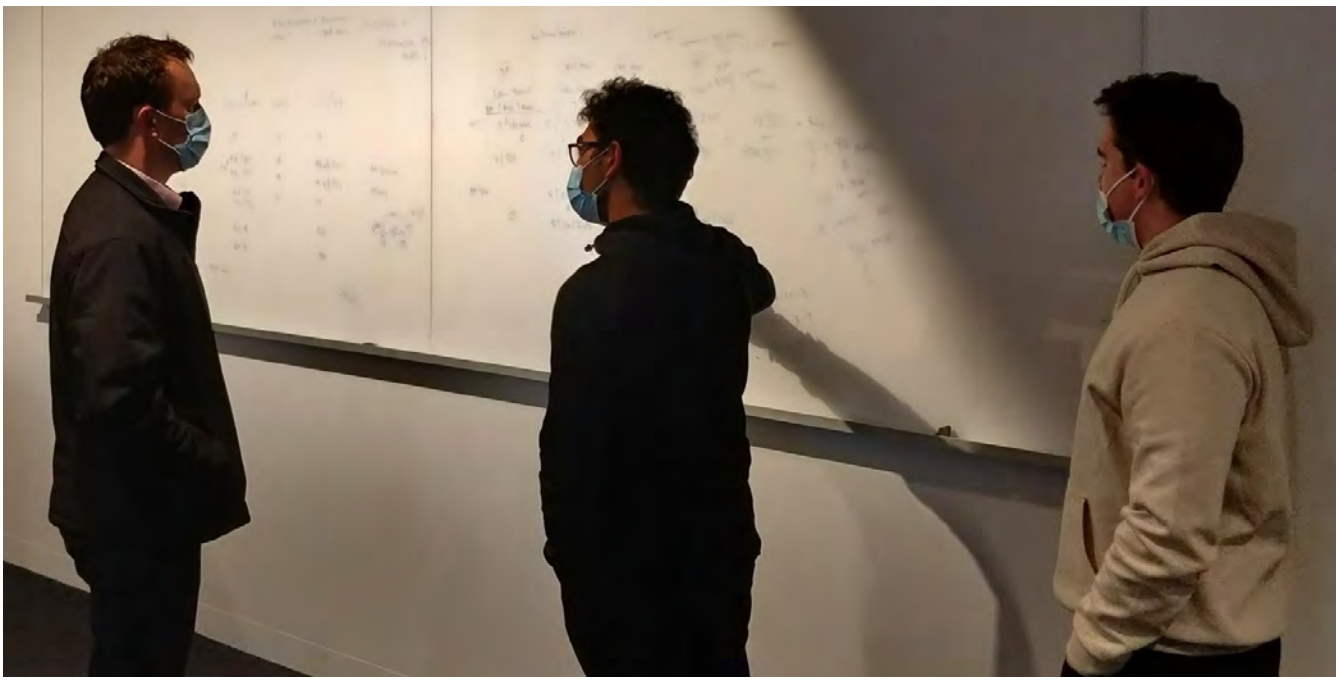
The following activities took place in 2021 as part of the **MEI*network*21** program.

ENERGY SYSTEMS SHORT COURSE

The **MEI*network*21 Energy Systems Short Course** was held over three intensive weeks in July 2021. Under the instruction of leading energy industry experts and practitioners, attendees were equipped with the skills to analyse the financial, technical and environmental performance of various energy projects.

The 2021 Short Course was taught by Dr John Burgess, a University of Melbourne Honorary Professorial Fellow, with the assistance of Mr Jonathan Anderson, a Senior Engineer working in the energy sector. Among the attendees were graduate students from the University of Melbourne and professionals from MEI's industry partners.

MEI received overwhelmingly positive feedback from course attendees, who said they gained valuable insights into the processes used to determine the viability of different energy investments, and the key components that underpin those decisions. MEI is grateful to Dr Burgess and Mr Anderson for sharing their time and knowledge, and for their dedication to creating a positive and engaging learning environment.



Students at the 2021 Energy Systems Short Course analysing the performance of an energy project.

ENERGY SYSTEMS SEMINAR SERIES

The **MEI*network*21 Seminar Series** was held as six online lectures from June to November 2021, and was delivered by specialists from industry and the University. The series aimed to provide attendees with a deeper understanding of the electricity supply chain. Topics spanned customers and demand; transmission and distribution networks; wholesale, financial and retail markets; and demand response and virtual power plants.

The presenters were Mr Tom Walker from the Australian Energy Market Commission, Mr John Theunissen of AusNet Services, Mr Paul Austin from the Australian Energy Market Operator, Mr Rob Koh at Morgan Stanley, Mr Nick Sissons representing Hydro Tasmania, and Professor Pierluigi Mancarella, MEI's Program Leader for Energy Systems.

The webinar recordings can be accessed on the MEI website.

MEI SYMPOSIUM 21

MEI held its fourth annual Symposium in December 2021. Held as a hybrid in-person and online event, MEI Symposium 21 showcased research by the University of Melbourne's graduate students, post-doctoral researchers and academic staff, and featured keynote presentations from leading national and international energy researchers.

Ms Anna Collyer, Chair of the Australian Energy Market Commission, delivered the opening plenary on how the transition to a net zero grid will meet consumers' needs for decarbonised, affordable and reliable energy. The opening plenary was followed by keynote presentations by experts on a range of energy topics, including Professor Kylie Catchpole from the Australian National University, Professor Doug Macfarlane from Monash University, Professor Ross Baldick from the University of Texas at Austin, and Dr Claire Vincent from the University of Melbourne.

The Symposium themes were divided across MEI's four research programs – Energy Systems, Power Generation and Transport, Hydrogen and Clean Fuels, and Energy Materials – with prizes awarded to outstanding doctoral or post-doctoral presenters in each theme.

MEI congratulates the following winners in each of the four categories:

Energy Systems
Awarded to: Mr Vincenzo Bassi
Presentation title: Extracting the physics of electrical networks using smart meter data: towards model-free voltage calculations

Power Generation and Transport
Awarded to: Dr Massimiliano Nardini
Presentation title: Aviation impact accelerator: accelerating the path towards net-zero aviation

Hydrogen and Clean Fuels
Awarded to: Dr Ehsan Soroodan Miandoab
Presentation title: Techno-economic analysis of membrane contactor systems for carbon capture

Energy Materials
Awarded to: Dr Calvin Lee
Presentation title: Waste not, want not: how singlet fission can deliver cheaper power by minimising solar panel losses

Ms Anna Collyer, Chair of the Australian Energy Market Commission, delivering the opening plenary at MEI Symposium 21.

SEMINARS, LECTURES AND WORKSHOPS

MEI hosted several other online seminars, lectures and workshops throughout 2021, including those listed below.

AEMO QUARTERLY DYNAMICS WEBINARS

The Australian Energy Market Operator (AEMO) publishes a Quarterly Energy Dynamics Report that provides market participants, businesses, consumers, governments and the wider energy community with updated information on dynamics, trends and outcomes in Australia's electricity and gas markets. MEI has become a key dissemination point for the findings of the quarterly report via the **AEMO Quarterly Dynamics webinars**.

At the release of each report, MEI invites guest speakers from AEMO to present the findings and stimulate discussion with diverse stakeholders. In 2021, MEI was pleased to host AEMO's Dr Jonathan Myrtle, Team Leader for Market Insights, and Mr Paul Austin, Group Manager for Market Insights, to speak at the four online seminars, held from February to November 2021.

As in past years, the regular seminars were well attended, with the shift to an online format enabling even greater participation by a national audience.

RESET: RESTORING AUSTRALIA AFTER THE PANDEMIC RECESSION

Economist and Professor Ross Garnaut launched a book in March, titled *RESET: Restoring Australia after the Pandemic Recession*. The online launch and accompanying discussion of the new book was hosted by MEI in partnership with the Faculty of Business and Economics and the publisher, Black Inc.

Online discussion with Professor Garnaut was moderated by Professor Abigail Payne, a Professor of Economics and Director of the Melbourne Institute, and Mr Rod Sims, Chair of the Australian Consumer and Competition Commission. Together, the speakers explored the book's themes, including Australia's post-pandemic path back to full employment and income growth, and why this depends on making good use of the opportunity to decarbonise our economy.

THE SOCIAL LICENCE – A PATHWAY OR STUMBLING BLOCK TO MEETING AUSTRALIA'S ENERGY NEEDS?

The topic for this online seminar, exploring the concept of a social licence for businesses to operate, was sparked by a research publication titled *Social licence and unconventional gas: A solution to, or component of, conflict?,* authored by Professor Fiona Haines from the University of Melbourne, and Professors Sara Bice and Helen Sullivan from the Australian National University.

A panel of researchers and community members at this online event explored the messy reality behind the concept of a social licence, drawing on the research to show how it can be drawn into conflicts between companies and communities, and how it can nonetheless play an important role in enabling a necessary but difficult conversation within and between communities, energy companies and government. Discussion was moderated by MEI Director, Professor Michael Brear.

SOLAR CITY, SMART CITY: TRANSFORMING THE URBAN ENERGY LANDSCAPE

During this seminar, researchers from the ARC Centre of Excellence in Exciton Science, Professor Anita Ho-Baillie from the University of Sydney and Professor Jacek Jasieniak from Monash University, discussed national and global trends in photovoltaics deployment in cities. They highlighted potential applications beyond conventional rooftop panels and large-scale arrays, including building-integrated technology, such as solar windows that generate power.

The event was opened by Exciton Science Director, Professor Paul Mulvaney, and included a panel discussion moderated by MEI Director, Professor Michael Brear.

MOVING SOUTH-EAST ASIA TO CLEAN ENERGY

In the face of growing impacts from climate change, how can Southeast Asia make the necessary transition to clean sources of energy, and what impact will this have on the urban and rural spaces in which people live?

Prominent Southeast Asian alumni and academics from the University of Melbourne joined a multi-national online panel to discuss this question, hosted by MEI Director, Professor Michael Brear.

PHD-LEVEL SHORT COURSE: ADVANCED MODELLING OF DER-RICH ACTIVE DISTRIBUTION NETWORKS

This five-day PhD-level short course was delivered by the Power and Energy Systems Group in partnership with MEI at the University of Melbourne. It covered fundamental and advanced modelling of active distribution networks with deep penetration of distributed energy resources (DER).

Topics under discussion included power flow and optimal power flow algorithms suitable for diverse applications of active distribution networks with DER, consideration for uncertainty arising from renewables, provision of flexibility and grid services from DER, distributed multi-energy systems and community energy systems, and fundamentals of distributed energy markets.

USING OPERATING ENVELOPES TO ENSURE NETWORK INTEGRITY - FROM CONCEPT TO REALITY

The high uptake of solar technology in Australia provides opportunities for households to provide services to the Australian Energy Market Operator (AEMO) through aggregators. As a result, power distribution companies need to ensure the integrity of their poles and wires. One solution is the use of operating envelopes.

In this online seminar hosted by MEI, Professor Nando Ochoa Pizzali and Dr Michael Liu from the University of Melbourne, together with Mr John Theunissen from AusNet Services and Mr Nick Regan from AEMO, led discussion on the benefits and challenges associated with the implementation of operating envelopes on real networks as part of the $28-million Australian Renewable Energy Agency-funded Project EDGE.

POPULAR ARTICLES

The following articles were authored by MEI researchers and Fellows. The articles appeared in *Pursuit*, the University of Melbourne's academic research publication, and *The Conversation*, a news website that publishes stories written by academics and researchers.

HOME-DELIVERED FOOD HAS A HUGE CLIMATE COST. SO WHICH CUISINE IS THE WORST CULPRIT?

The Conversation, 19 January 2021
By Professor Robert Crawford, University of Melbourne

Of the five cuisines examined, packaging from burger meals was responsible for the most emissions.

CREATING CLEAN TRANSPORT FUELS FROM WASTE

Pursuit, 8 April 2021
By Associate Professor Mohsen Talei, Dr Dominic Davis, Professor Michael Brear, University of Melbourne, and Dr Davy Brouzet, Stanford University

By extracting biofuel from agricultural and urban waste, researchers hope to create a low-cost, zero emission transport fuel for the future.

THE IMPACT OF AIR POLLUTION ON LIFE EXPECTANCY

Pursuit, 5 August 2021
By Dr Nilakshi Waidyatillake, Professor Mark Stevenson and Professor Shyamali Dharmage, University of Melbourne

Air pollution is already having devastating effects on human health, now a new study shows how particulate matter in the air is associated with premature deaths.

AUSTRALIA GIVEN SERIOUS HEALTH WARNING ON CLIMATE CHANGE

Pursuit, 21 October 2021
By Associate Professor Celia McMichael and Professor Mark Stevenson, University of Melbourne

Research monitoring the health impact of climate change highlights the escalating global emergency and the threat to the Australian way of life.

TECH CAN DO A LOT, BUT WON'T GET US TO NET ZERO ON ITS OWN

Pursuit, 7 November 2021
By Professor Michael Brear, University of Melbourne

The Morrison Government's emphasis on technology to drive down emissions will still need taxes and subsidies to achieve net zero.

THERE'S AN ENORMOUS GEOTHERMAL POOL UNDER THE LATROBE VALLEY THAT CAN GIVE US CHEAP, CLEAN ENERGY

The Conversation, 2 December 2021
By Dr Graeme Beardsmore, University of Melbourne

It's 650 metres below the surface, across 6,000 square kilometres – and has been overlooked for far too long.

GOVERNMENT SUBMISSIONS

RESPONSE TO ACOLA JANUARY 2021 CONSULTATION PAPER

The University of Melbourne was invited by the Australian Council of Learned Academies (ACOLA) to comment on the January 2021 *Research Priorities Consultation Paper* for the Australian Energy Transition Research Plan.

Date of submission: 26 February 2021
Lead Academic: Professor Michael Brear
In consultation with: Professor Robin Batterham, Professor Mark Cassidy, Dr Sangeetha Chandra-Shekeran, Professor Peter Cook, Professor John Freebairn, Professor Ross Garnaut, Professor Lee Godden, Professor Ralf Haese, Professor Fiona Haines, Professor David Jamieson, Professor Sandra Kentish, Professor Pierluigi Mancarella, Associate Professor Malte Meinshausen, Professor Paul Mulvaney, Associate Professor Kathryn Mumford, Professor Jacqueline Peel, Professor Richard Sandberg, Professor Mike Sandiford, Associate Professor Robyn Schofield, Professor Geoff Stevens, and Professor John Wiseman.

VICTORIAN RENEWABLE ENERGY ZONES DEVELOPMENT PLAN, DIRECTIONS PAPER

In this Response Document prepared for the Department of Environment, Land, Water and Planning, the University of Melbourne provided feedback to the *Victorian Renewable Energy Zones Development Plan Directions Paper*, which discussed the development of the "VicGrid" body to facilitate the development of Renewable Energy Zones (REZs) in Victoria.

Date of submission: 31 March 2021
Lead Academic: Professor Pierluigi Mancarella
In consultation with: Professor Michael Brear, Mr Guanchi Liu, Dr Sebastian Püschel-Løvengreen, Dr Sleiman Mhanna and Dr Lingxi Zhang

MAPPING THE AUSTRALIA-KOREA HYDROGEN INTERSECTIONS

MEI was invited by the Australia-Korea Business Council to comment on their discussion paper *Mapping the Australia-Korea Hydrogen Intersections*, which explored a prospective hydrogen supply chain and associated opportunities for Korea and Australia.

Date of submission: 12 March 2021
Lead Academic: Professor Michael Brear
In consultation with: Professor Mark Hargreaves, Professor Michael Wesley, Professor Justin Zobel, Professor Adrian Little, Associate Professor Kathryn Mumford, Professor Richard Sandberg, Professor Pierluigi Mancarella, Ms Kate Taylor and Ms Carlene Wilson.

COMMUNICATIONS AND MEDIA

Through the following communications channels, MEI aims to contribute to the national energy debate by presenting a range of views on relevant and critical industry issues.

NEWSLETTERS

energy@melbourne

The Melbourne Energy Institute's monthly external newsletter, **energy@melbourne**, is our key communication tool. With a subscriber list of over 5500, information about MEI's research as well as important news and events is sent directly to stakeholders in industry, government, community and academia.

MEDIA

Could a plug-in hybrid EV be right for you?

In this Renew article, Professor Michael Brear discussed the benefits of plug-in hybrid electric vehicles and battery electric vehicles, and how vehicle size impacts lifecycle emissions.
Renew Magazine, January-March 2021 edition

Past, present and future of Australia's oil and gas sector

In the lead up to the 40th Annual AOG Energy Conference, Professor Michael Brear was interviewed about the recent history and likely future of Australia's oil and gas sector, including the movement towards cleaner energy sources such as hydrogen.
AOG Energy Industry News, 11 February 2021

What to do with all this wind

Professor Michael Brear was interviewed by ABC 774 to discuss Australia's wind resources and the impact of renewable generation on the electricity grid.
ABC 774, 12 June 2021

We're at ground zero on carbon emissions target

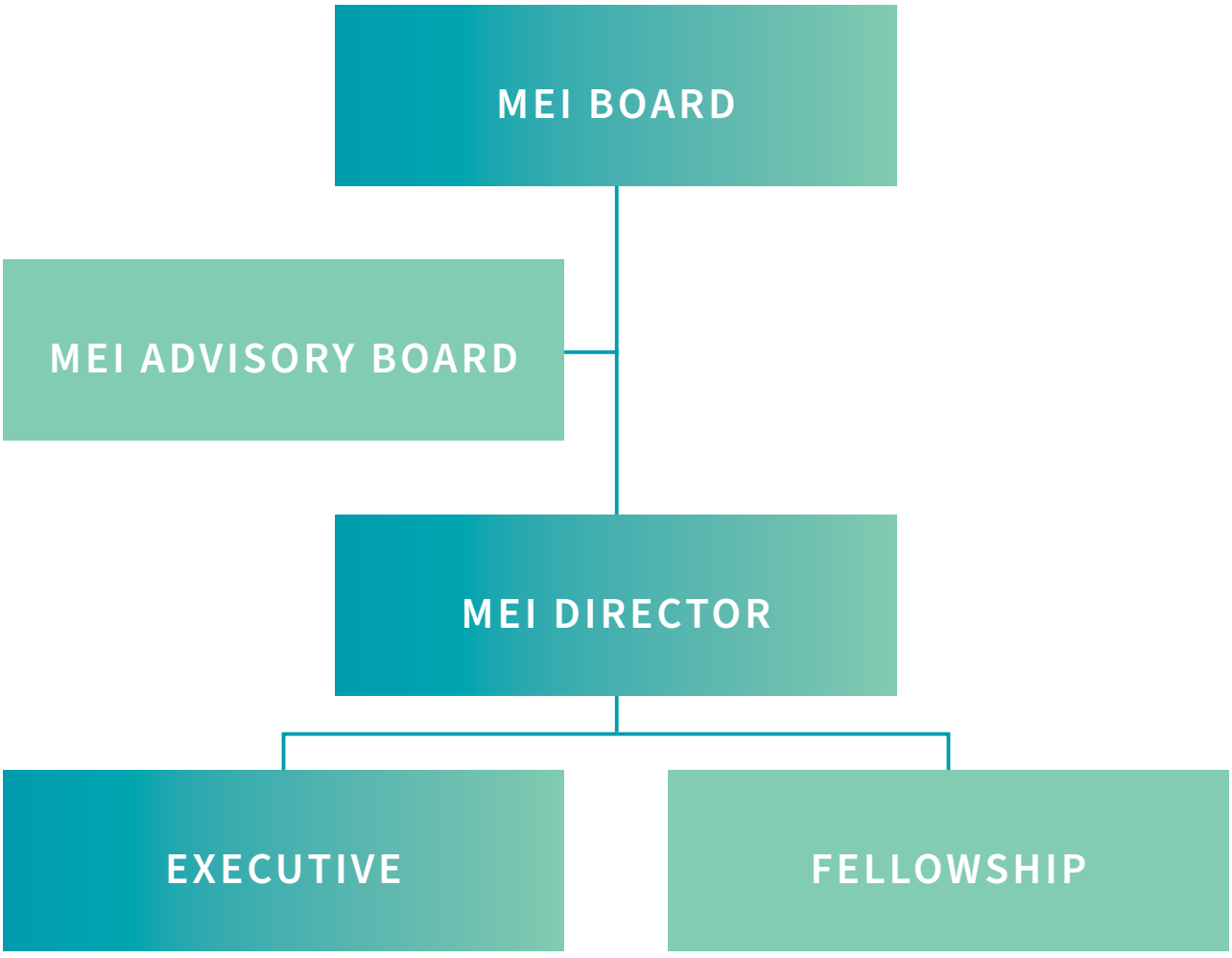
In an opinion piece published in The Australian, former Chief Scientist and Emeritus Professor Robin Batterham, and former Deputy Prime Minister John Anderson discussed the role of soil carbon sequestration in achieving carbon emissions target by 2050.
The Weekend Australian, 10 July 2021

Transitioning to a clean energy system

Following the United Nations Climate Conference, Professor Michael Brear was interviewed by the ABC News Radio National breakfast program to discuss what technology is required to meet climate targets.
ABC News Radio National, 4 November 2021

GOVERNANCE

The Melbourne Energy Institute reports to the MEI Board for operational matters. The Institute Director, team of professional staff and the Executive Committee work together to operate MEI, and the Advisory Board and Fellows provide strategic advice.



MEI BOARD

Professor Mark Hargreaves, *Pro Vice-Chancellor (Research Partnerships and Infrastructure) (Chair)*

Professor Stuart Wyithe, *Associate Dean, Research, Faculty of Science*

Professor Frank Vetere, *Deputy Dean (Engagement), Faculty of Engineering and Information Technology*

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Mr Michael Bielinski, *CEO Siemens Energy*

Ms Mel Cutler, *Head of Purpose, Strategy and Environment, ANZ*

Ms Sally Farrier, *Company Director*

Mr John Theunissen, *Manager Network Innovation, Regulated Energy Services, AusNet Services*

Mr Tony Wood, *Energy Program Director, Grattan Institute*

EXECUTIVE COMMITTEE

Professor Michael Brear, *Director, Melbourne Energy Institute (Chair)*

Ms Anita La Rosa, *Institute Manager, Melbourne Energy Institute*

Professor Pierluigi Mancarella, *MEI Program Leader Energy Systems, and Chair Professor of Electrical Power Systems*

Associate Professor Kathryn Mumford, *MEI Program Leader Hydrogen and Clean Fuels, and Associate Professor in the Department of Chemical Engineering*

Dr Adrian Panow, *Director Major Projects, Melbourne Energy Institute*

Professor Richard Sandberg, *MEI Program Leader Power Generation and Transport, and Chair of Computational Mechanics*

Associate Professor Wallace Wong, *MEI Program Leader Energy Materials, and Senior Lecturer in the School of Chemistry*

FINANCIAL SUMMARY

INTERNAL INCOME	$K
Core funding from Deputy Vice-Chancellor (Research)	970
Other income	57
TOTAL INTERNAL INCOME	**1,027**
EXPENDITURE	
Institute staff salaries	574
Administration & general costs	10
Events & communication	10
Research project support salaries	308
Research project seed funding	80
Partnership development	31
TOTAL EXPENDITURE	**1,013**
EXTERNAL INCOME	
ARC	0
Industry – direct contract and leveraged	10,782
Government	8,518
Philanthropy	1,500
TOTAL EXTERNAL INCOME	**20,800**

THE UNIVERSITY OF MELBOURNE

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