



MELBOURNE
ENERGY INSTITUTE



Melbourne Energy Institute

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Background

Changes within the energy sector have been rapid, as new technologies, business models and policy settings emerge to address the environmental impacts of energy production. Our energy system is undergoing transformation, this presents new opportunities and challenges that are crucial for national and global policy considerations.

The increasing recognition that our energy systems need to be made more sustainable, environmentally benign and adaptable, while also providing reliable and affordable supply to more people presents a daunting challenge. In particular the prospect that rising greenhouse gas concentrations are contributing to unprecedented and potentially irreversible climate change makes redesigning our energy systems one of the most important challenges of our time.

Since the Institute was launched in 2010, the change within the energy sector has been rapid. As new technologies, business models and policy settings emerge, we see just how quickly new pathways can be forged. To ensure these pathways lead to a certain energy future, they must be informed by

a deep understanding of environmental impacts, regulatory frameworks and social equity issues. Framing such pathways requires research strategies that transcend traditional lines of enquiry to link many different ways of thinking that inform how modern societies work and prosper.

The Melbourne Energy Institute engages researchers across seven facilities at the University of Melbourne to help meet this challenge. It is one of a family of five institutes, that include social equity, sustainability, neuroscience and information and communications technology, that together comprise the Melbourne Research Institutes.



Message from the Director

Since 2010, the Melbourne Energy Institute has worked with faculties including Economics, Science, Engineering, Law, Architecture, Medicine and Arts to help develop interdisciplinary energy research programs. New funding secured for these programs totals approximately \$37 million.



The year of 2015 marked the Institute's sixth year of operation and working in partnership with faculties we are delighted to continue our program of expanding the University's energy research portfolio. While programs have been varied in scope covering energy resources, production, distribution and consumption, waste capture and storage, and economics and policy, the connecting theme has been developing University capacity in meeting the challenges of large-scale, low-emission energy systems.

The building of significant partnerships between industry and government departments and agencies has been central to the growth of the Institute's programs. In 2015, the Institute furthered research in areas such as energy storage mechanisms, renewable energy integration, energy market design, carbon capture and storage, direct geothermal energy, future grid scenarios and sedimentary basin management.

Our support of early career researchers has also been a central part of our growth. In 2015, Dr Sara Bice, whose position the Institute helped seed, has been awarded the prestigious Westpac Bicentennial Research Fellowship. Sara was one of four researchers in Australia to receive this honour. Working alongside colleagues at the Melbourne Energy Institute Sara's research interrogates the regulatory efficiency of Australia's natural resources to find ways that community; governments and resource developers can optimise underground resource use for the very long term. Sara leads the Institute's sedimentary basin management initiative, with a focus on issues surrounding social license to operate.

The Institute funds positions like Sara's because we believe that fostering the talent and ambition of early career researchers is important in supporting them to become the future thought

leaders that will help us realise a low emission energy system.

The Institute continued to be impressed with the progress of international research group the Basin GENESIS HUB lead by the Institute's energy geophysics leaders Professor Louis Moresi and Professor Tim Rawling. In 2015, the value of the HUB was recognised receiving an additional \$600k of external funding. The work of Tim and Louis through programs such as the HUB and Australian Geophysics Observation Laboratory has made the Institute's early vision of establishing the University as a global leader in energy geophysics a reality.

Our contribution to our national energy debate continues with our Energy Futures Seminar Series providing a forum for academia, community, industry, and government to discuss critical future energy issues. In partnership with the Grattan Institute, our 2015 seminars continued to attract a large and engaged audience. A public talk partnership with The Wheeler Centre furthered our engagement.

Looking forward, 2016 will see a number of exciting developments including the growth of the Australian-German Climate and Energy College, which to-date has a strong PhD cohort of 28. The College is a partnership with a consortium of German universities and the Melbourne Sustainable Society Institute. The establishment of an international PhD program in the area of energy markets, building on collaboration with the London School of Economics and Political Science, University of California, Berkeley and Stanford University is an exciting goal for 2016.

We would like to offer our sincere thanks to Professor Robin Batterham for acting as the Institute's interim director for part of 2015.

Prof Mike Sandiford

Major Initiatives

BASIN GENESIS HUB

The project will develop quantitative, cutting edge data analysis techniques to underpin the testing of new concepts for understanding basin structures, and aid in driving sustainable use of basin resources.

Faculties:

Science and Engineering

Lead Academics:

Prof Louis Moresi and Prof Tim Rawling

Partners:

The University of Sydney, Curtin University, The California Institute of Technology, Geoscience Australia, Chevron USA, Oil Search, Statoil, Intrepid Geophysics and 3D-GEO

The Australian Research Council (ARC) Research Hub for Basin Geodynamics and Evolution of Sedimentary Systems (Basin Genesis Hub) is a showcase of connecting “Big Data” analysis and high-performance computing in an open innovation framework. The hub will fuse multidimensional data into 5D basin models (space and time, with uncertainty estimates) by coupling the evolution of mantle flow, crustal deformation, erosion and sedimentary processes using open-source modelling tools.

Sedimentary basins capture Earth’s sea level, climate history, and the variation of the surface topography due to geodynamic, tectonic, and surface processes. They host a range of conventional and unconventional hydrocarbon resources of critical importance for the continued functioning of modern society. We increasingly rely on the same basins for oil, gas, geothermal energy, and water, and managing these competing uses requires much greater sophistication.

The overarching objective of the Basin GENESIS Hub is to transform knowledge of into an exploration tool. To achieve this, the project will develop new high-performance simulation and data mining tools, making use of new petascale computing capabilities, will connect big, multidimensional data sets to cutting edge machine learning and modelling algorithms to cross a wide spectrum of spatial and temporal scales. These new approaches will help address a variety of issues in the context of basin structure and evolution for sustainable deep and shallow earth resource extraction and management.



AUSTRALIAN-GERMAN CLIMATE AND ENERGY COLLEGE

The College addresses some of the most pressing issues facing society today; climate change and energy transitions, and strives to deliver the research capability that will bring society towards a low emissions future.

Faculties:

Science, Arts, Law and Engineering

Lead Academics:

A/Prof Malte Meinhausen, Prof Ross Garnaut, Prof Robin Batterham, Prof Mike Sandiford, Prof Robyn Eckersley, Prof John Wiseman and Prof Brendan Gleeson

Partners:

Potsdam Institute for Climate Impact Research, Humboldt University, Technical University of Berlin and University of Potsdam

The Australian-German Climate and Energy College, established in 2013 with support from the Institute and a consortium of universities in Germany, is a postgraduate PhD research program that seeks to address the interdisciplinary and global challenges posed by climate change and energy transitions.

The College provides a collaborative, cohort based PhD environment in which research is undertaken across four key research clusters; climate systems, climate impacts, mitigation strategies and energy systems. Topics are varied in scope covering the integration of renewable energy into existing energy infrastructure, to evaluating societal stability during internally and externally induced transitions.

2015 was a busy and successful year for the College; the curriculum was expanded, with twenty eight PhD candidates now active across a broad range of climate and energy topics. The College has now published eighteen articles in refereed journals, these examine pertinent issues such as 'Flexible Electricity Tariffs: Power and Energy Price Signals Designed for a Smarter Grid'.

The year had a number of highlights including meeting with Al Gore during his 2015 visit to Melbourne and having a strong presence in Paris for the United Nations Framework Convention on Climate Change (UNFCCC) Conference of Parties (COP 21). Following COP, the College produced and presented summaries providing a comprehensive overview of all submitted Intended Nationally Determined Contributions (INDCs).

The College's engagement with public debate has continued with 29 articles now published on *The Conversation*. The College's Science and Pretzels and Hot Seat seminars continue to provide PhD candidates with access to insights from renowned speakers across a range of fields, from within and outside of academia.

For more information please visit: www.climate-energy-college.net



Al Gore with members of the Australian-German Climate and Energy College during his visit to Melbourne in 2015.

Major Initiatives

SEDIMENTARY BASIN MANAGEMENT INITIATIVE

This project advances a 'whole-of-resource' approach to basins management and evidence-based policy for complex issues with a particular focus on social risk and social licence to operate.

Faculties:

Arts, Science, Law and Engineering

Lead Academics:

Dr Sara Bice, Prof Mike Sandiford, Prof Fiona Haines and Prof Helen Sullivan

Partners:

The University of Newcastle, The University of Adelaide, Carlton Connect Initiative, NICTA, NSW Office of Chief Scientist, Geoscience Australia and NOPTA

Sedimentary basins provide 90% of Australia's primary energy and water for agriculture and rural populations. Despite this, information to support strong management and governance decisions is lacking.

Among the general Australian public, sedimentary basins are poorly understood and little discussed. Yet, the ways in which sedimentary basins are used today will affect our communities tomorrow as our sedimentary basins are increasingly explored for new resources and services, such as unconventional gas, sub-surface storage of CO₂ waste and geothermal energy.

In Victoria, research suggests that the Gippsland Basin offers great potential for carbon capture and storage, especially to offset nearby Latrobe Valley brown coal mining activities. Decisions about sedimentary basin use and their consequences have flow-on effects for Victorian environments and communities. This means we require a whole-of-society approach to resources management that considers

the economic, environmental and social costs and benefits beyond those linked to individual end-users. Yet, it is these individual end-users, in the form of governments and corporations, who make the important decisions about whether and how the resources or storage potential of Victoria's (and Australia's) sedimentary basins are used. This situation places governments and corporations in a position of substantial social responsibility.

The Sedimentary Basin Management Initiative's social science research program tackles this complex circumstance through a holistic approach to identifying, addressing and mitigating the current and potential social impacts of decisions about sedimentary basins management. It applies robust social science research using a multidisciplinary approach, drawing upon leading geoscience, economics and legal studies. It also prizes engagement of key community, government and corporate stakeholders to translate research effectively to inform policy.



ACHIEVING COST-EFFECTIVE ABATEMENT FROM AUSTRALIAN ELECTRICITY GENERATION

By implementing a mix of wind, solar concentrating thermal energy and combined cycle natural gas turbines, an emission reduction scenario of 80-90% by 2050 is economically feasible.

Faculties:

Science and Engineering

Lead Academics:

Dr Roger Dargaville and Prof Michael Brear

Partners:

The University of New South Wales, Australian Energy Market Operator, GE, Bureau of Meteorology and Australian Renewable Energy Agency

Achieving deep greenhouse emissions abatement from Australia's National Electricity Market (NEM) by 2050 requires changes to the way energy is produced and consumed. Under funding from the Australian Renewable Energy Agency (ARENA) a team at the University of Melbourne identified least cost technology pathways for achieving emissions reductions in the NEM.

The project involved undertaking large-scale optimisations that consider the impact of current and future fossil plants, with and without carbon, capture and storage (CCS), renewable plants and nuclear plants as well as the performance of an extended renewable energy target (RET).

These optimisations revealed that by implementing a mix of wind, solar concentrating thermal energy and combined cycle natural gas turbines, an emission reduction scenario of 80-90% by 2050 is economically feasible. Though, achieving 100% renewable energy is considerably more costly due to the required large overcapacity.

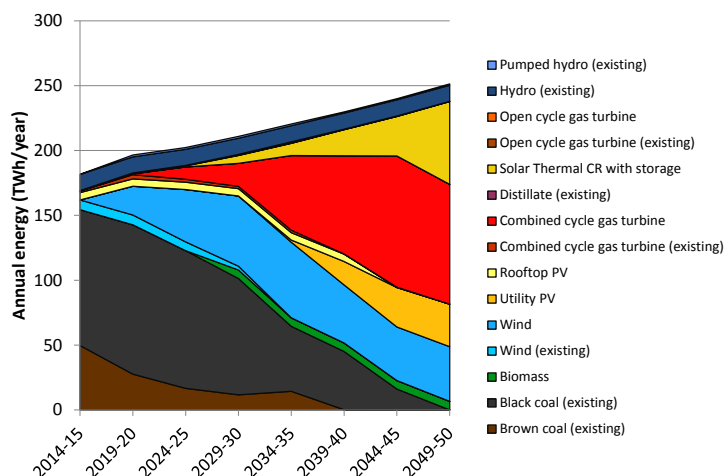
Encouragingly, this study has shown that that optimal pathways up for 2030

are much the same for policy settings with a carbon price or with an extended RET and that current policy settings are not leading along a sub-optimal pathway. Beyond 2030, policy must directly focus on emissions rather than a RET.

This study suggests that Australia is currently in a fortunate position. Australia has utility scale technologies, renewable and non-renewable resources, an electricity market design and an abatement policy (the RET) that permits continued progress towards deep greenhouse gas abatement in its electricity sector.

However, long-term uncertainty must be acknowledged, decarbonisation should be viewed as a 'receding horizon' problem. This means that we identify a longer-term abatement target and then continuously refine and/or adopt policies that are consistent with this target in the nearer term. Future analysis will help determine when a transition from a form of RET is necessary and whether deploying nuclear and CCS is ultimately attractive.

Example output of the project demonstrates that 80% abatement of greenhouse gas emissions can be achieved by 2050 assuming no nuclear or CCS



Major Initiatives

ENERGY MARKETS PROGRAM

The Energy Markets Program looks at market challenges around next generation electricity with the ambition of establishing the University as an internationally recognised hub for energy economics research.

Faculty:

Business and Economics

Lead Academic:

Prof John Freebairn, Dr David Byrne, Dr Renaud Coulomb and Dr Leslie Martin

Partners:

Australian Government Treasury, State Government of Victoria Department of Treasury and Finance and Billcap

Advances in digital and information technology are radically changing the way people buy and consume energy through helping households make better-informed electricity usage decisions. Under an ARC linkage grant 'Technology Transforming Markets: Large-Scale Field Experiments in Electricity Use' the Energy Markets Program is analysing this trend.

The project has drawn on a partnership with start-up software company Billcap to provide the first published insights into the behaviour of consumers in a competitive and smart-meter enabled retail electricity market.

In 2015, the project grew with the establishment of two new engagements, a large Victorian electricity retailer (with >250,000 customers), and another with South East Water (with >750,000 customers). The program is now running four innovative large-scale field experiments that inform policy-relevant questions surrounding flexible electricity pricing, solar panel adoption and electricity use.

"The energy industry has long theorised on the impact of smart meters and related technologies. This research aims to deliver concrete insights to benefit both consumers and the energy industry" – Yann Burden, CEO BillCap

The program is an example of the way partnerships between the University, private sector and government create the opportunity for research that is of high value for policymakers and academics alike.

Through the Energy Markets Program the MEI is helping the University develop the critical research capacity required to become an international leader in energy and resource economics. To achieve this the MEI provided support for Dr Leslie Martin's position in 2014. In 2015, this continued with the appointment of Dr Renaud Coulomb, Dr Coulomb's research focuses on issues of optimal taxation of resource-extracting firms, representing an invaluable addition to the team.



cmd CENTRE FOR
MARKET DESIGN

A CONSORTIUM OF



Australian Government
The Treasury



Department of
Treasury and Finance



FACULTY OF
BUSINESS &
ECONOMICS

GEOHERMAL PROGRAM

Direct geothermal systems provide an exciting way for homes and businesses to reduce their own energy bills and carbon footprint through using shallow ground as a heat source and sink for heating and cooling buildings.

Faculties:

Science and Engineering

Lead Academics:

Prof Ian Johnston and Dr
Guillermo Narsilio

Partners:

State Government of Victoria (DEDJRT), Geotechnical Engineering, Direct Energy, Golder Associates, the University of Cambridge, the University of Southampton, KAIST, Korea University and the University of California, San Diego

Direct geothermal systems use shallow ground as a heat source and sink for heating and cooling buildings, using ground heat exchangers and heat pumps. They provide an exciting way for homes and businesses to reduce their own energy bills and carbon footprint. The project is trialling a number of different types of instrumented vertical and horizontal ground loop systems, including energy piles (building foundations fitted with HDPE piping) and borehole installations to depths of 30 to 50m. This research is showing that substituting common heating and cooling systems with geothermal systems in both residential and industrial areas can reduce overall energy consumption and thus reduce greenhouse gas emissions.

The work has been disseminated in 2015, in particular via an Invited Lecture held in Barcelona (1st International Symposium on Energy Geotechnics) and a 'Spotlight' Lecture in Kansas City (International Ground Source Heat Pump Association Conference).

In collaboration with partners, Dr Narsilio, from the Department of Infrastructure Engineering will

develop new models for studying the performance of ground heat exchangers, including energy piles, to improve the design and efficiency of geothermal systems for cooling and heating buildings, contributing to reducing energy consumption and greenhouse gas emissions. The trial has received substantial support from the Victorian Government and the Australian Research Council, under the prestigious Future Fellowship scheme.

Together with industry partners Ground Source Systems Pty Ltd and Golder Associates Pty Ltd, The University of Melbourne is exploring new applications of the technology within the rural industries – typically deprived of natural gas – such as heating and cooling chicken brooder houses.



Linden Jensen-Page running a Thermal Response Test to estimate the thermal conductivity of the ground at Footscray

Flagship Energy Research Programs

GEOLOGICAL CARBON STORAGE PROGRAM

The Geological Carbon Storage Program of the Peter Cook Centre for Carbon Capture and Storage Research has established the University and Victoria as a leading international centre of carbon capture and storage research.

Faculties:

Science and Engineering

Lead Academics:

Prof Ralf Haese and Prof Stephan Matthai

Partners:

Rio Tinto, State Government of Victorian, and the Cooperative Research Centre for Greenhouse Gas Technologies (CO2CRC)

Taking a holistic approach to issues of sustainability posits carbon capture and storage (CCS) as an essential element in effective emissions reductions. As such, the Geological Carbon Storage program of the Peter Cook Centre for Carbon Capture and Storage (CCS) Research was established in 2012. The research performed underpins the development of enhanced technologies for carbon capture and storage in Australia.

2015 had a number of highlights including, the refurbishment and new establishment of dedicated CCS laboratories within the Department of Chemical and Biomolecular Engineering and the School of Earth Sciences worth over \$11 million. These new laboratories have many exceptional capabilities; one example is Prof Haese's Fluid Flow and Geochemistry Laboratory equipped with core flood facilities and a micro-CT scanner. The latter can image rocks in 3-dimensions with a resolution in the micrometre range, which allows the reconstruction of the pore network geometry used for pore scale modelling.

A major field experiment at the CO2CRC Otway Project site was completed with a report on the impact CO2 impurities

such as sulphur dioxide, nitrogen dioxide and oxygen on geochemical processes and water quality in a CO2 storage reservoir. The project was carried out in collaboration with the CO2CRC and funded by a consortium including industry partners from Japan.

With the appointments of Prof Ralf Haese, Chair of Geological Carbon Storage and Prof Stephan Matthai, Chair in Reservoir Engineering, supported by the Institute, the University has now established itself as the leading University research team in the field of CO2 storage complementing the long record of achievement in carbon capture research lead by Prof Geoff Stevens. The CO2 Capture Program fills an important gap as it undertakes both research to reduce capital and operational costs of CO2 capture technology, and research with the aim to reduce the risks associated with the injection and geological storage of CO2. The unique opportunities provided by the Otway subsurface laboratory facility managed via the CO2CRC place the University and Victoria as a leading international centre of CCS research.



CARLTON CONNECT INITIATIVE

The Carlton Connect Initiative (CCI) is creating Australia's premier innovation precinct anchored by the University of Melbourne. As an open platform, CCI unites talented people who extend and deepen the application of knowledge throughout the Australian economy.

Partners include:

Melbourne Business School, IBM Corporation, Health XL, the Herald Sun, GE, Autodesk, Moral Fairground, Melbourne Farmers Markets, TEDx Melbourne and the City of Melbourne

Arguably the buzzword of 2015, "innovation" has become a prominent theme in the national conversation.

However, the theme of innovation is not a new one for the University. As evidenced by initiatives such as the bionic ear, Fibrotech and now Carlton Connect, the University of Melbourne has a strong tradition of fostering innovation and a proud history of supporting innovators. Certainly, the increased prominence of the topic in public debate is something the University welcomes, and is particularly encouraged by the bipartisan approach this agenda encouraged in our political leaders in 2015.

In 2015, the CCI Innovation Precinct truly began to blossom, with vibrant on-site partners moving into the newly-refurbished LAB-14 building. As the precinct develops, it is easy to see the seeds of a more vibrant, knowledge-driven future for Australia taking root here in Carlton. Or as the Leader of the Opposition, the Hon. Bill Shorten, said at his on-site press conference "the future is in places like the Melbourne Accelerator Program, backing highly-skilled, high-wage jobs for the future".

In 2015, the CCI continued progress on creating a central place where,

together with university, business and government partners, CCI can apply fresh thinking to pressing social challenges and create commercial opportunities in the impact areas of water, food, energy and urban futures.

Throughout 2015, a number of our activities were focused on fostering opportunities within the energy space. In particular, we were delighted to welcome Relectrify (www.relectrify.com) into the building as a MAP15 startup. Relectrify works on battery recycling technology to make energy storage solutions more affordable.

As part of engaging the public on the future of energy, CCI ran a number of events, including a TEDx Melbourne with Ford on the future of transport and the first ThoughtLAB-14 for 2015. CCI and GE also co-hosted Australia's first industrial hackathon. #GEhack2015 participants worked with industry experts to solve challenges faced by key industries in Australia: energy optimisation, fuel efficiency, safety, asset tracking and quality assurance.

For more information about the Carlton Connect Initiative please visit: www.carltonconnect.com.au



Flagship Energy Research Programs

ELECTRIC VEHICLES RESEARCH GROUP

Electric vehicles show great promise as a technology that will allow greater energy security and greenhouse gas reduction in the transport sector. However, the charging of electric vehicles puts additional strain on the electricity grid, and if uncontrolled can lead to unexpected and undesirable effects.

Faculty:

Engineering

Lead Academics:

Prof Iven Mareels, A/Prof Marcus Brazil, Dr Tansu Alpcan and Dr Julian de Hoog

Partners:

Ausnet Services, United Energy, Ergon Energy, CSIRO, DiUS Computing, Axiflux and NICTA

The electricity grid is evolving. Many technologies have been developed or popularized in recent years. These technologies include electric vehicles (EVs) and distributed generation, such as rooftop solar photovoltaics (PVs) systems.

Melbourne School of Engineering researchers and industry partners have been working to develop an understanding of the type of demand-response system required to manage both a high penetration of EVs and PVs. In order to examine their impact, real household demand data, vehicle travel profiles and models of actual distribution networks as provided by the industry partners are used.

Research showed that with uncontrolled EV charging, existing networks can only sustain 10-15% penetration of electric vehicles. However, with an optimal charging policy (informed by electricity market spot price, state of charge of individual batteries, present and anticipated network loads) 80% penetration could be sustained with current network infrastructure. A novel and fair mechanism has been developed empowering EV users to

express their preferences regarding charging priorities while respecting the underlying grid constraints.

To manage the PVs on the grid, novel distributed demand management schemes have been developed, to regulate flexible loads so that overall demand can be flattened and the PV generation curtailed when necessary to regulate voltages and prevent reverse power flow.

This research has been conducted with the objective of improving the efficiency and cost-effectiveness of battery management systems for lithium-ion batteries. A prototype of a new balancing system layout for EVs was developed that removes the need for a backup battery. Development of battery models for use in simulations of the distribution power grid impact under various assumptions of electric vehicle charging.



Tesla, 2015

CLEAN AIR AND URBAN LANDSCAPES RESEARCH HUB

The mission of the Clean Air and Urban Landscapes (CAUL) is to take a comprehensive view of the sustainability and liveability of urban environments.

Faculties:

Science, Arts, Law and Engineering

Lead Academics:

Prof Peter Rayner and Dr Kirsten Parris

Partners:

RMIT University, The University of Wollongong and The University of Western Australia

The Clean Air and Urban Landscapes Hub was established in December 2014. The CAUL Hub is a consortium of four universities, participating in the National Environmental Science Programme funded by the Australian Government's Department of the Environment. The mission of the CAUL Hub is to take a comprehensive view of the sustainability and liveability of urban environments.

In its first full year of operation the CAUL Hub has concentrated on planning and development for its research and communication activities across the six year lifespan of the project. This has included:

- Development of the Hub's Research Plan, launched in July 2015 in Western Sydney by Parliamentary Secretary for the Minister for the Environment Bob Baldwin
- An internal all-hub conference held at the University of Melbourne in July 2015
- Consultation meetings with stakeholders and research partners in four cities (Canberra, Melbourne,

Perth and Sydney) throughout August 2015

- Development of associated strategies including the Hub's Indigenous Engagement and Participation Strategy and the Communications and Knowledge Transfer Strategy
- Establishment of a CAUL Hub office at the University of Melbourne, Hub website (www.nesurban.edu.au) and communications materials.

The research activities for the CAUL Hub commenced in 2015. A number of research outputs have already been achieved.

A highlight of the CAUL Hub's activity in 2015 was the work on the development of research protocols for academic researchers working collaboratively with Indigenous Australians in urban environments. This work included a two-day workshop held at the University of Melbourne in October 2015. This workshop was filmed and a short video will be available for researchers on the CAUL Hub website in early 2016.



Projects in Development

ENERGY STORAGE

Novel energy storage technologies have the potential to radically change the way renewable energy is integrated and deployed.

Faculties:

Science and Engineering

Lead Academics:

Prof Paul Webley, Prof Robin Batterham, Dr Roger Dargaville, and Mr Tim Forcey

Partners:

Carlton Connect Initiative, The Australia Institute and Arup

The potential and importance of energy storage is becoming greater as the penetration of renewables continues to increase and fossil plants are retired. South Australia is the epicenter of this experiment with 34% of energy generated in the state in 2015 coming from wind power. This penetration is large by any international standard, and so there is much attention being given to ways to improve the reliability of the grid. There is a broad range of storage technologies available, all with different characteristics. Lithium ion and lead acid batteries, compressed and liquid air, hydrogen and pumped hydro technologies operate at different scales; have different costs and charge and discharge at different rates. These factors mean that the optimal mix of storage will be complex and will depend on the location within the grid.

The MEI is researching a broad range of storage technologies, not just from a technical point of view, but also an economic and integration point of view. Continuing previous programs

examining pumped hydro and liquid air energy storage, in 2015 the MEI looked into hydrogen and ammonia storage. Hydrogen and ammonia are quite different to the other technologies mentioned above as they can be transported, and could potentially be a export commodity. The reason for studying ammonia is that despite the lower energy content, it is much easier to transport, being compatible with existing LPG transportation infrastructure. Ammonia is also a widely used chemical in industry and so has multiple other uses other than being returned to electrical energy.



CENTRE FOR ENERGY SYSTEMS

The Centre is aimed at filling a gap in the Victoria's and Australia's energy research and training capacity, bringing together academia and industry to build solution oriented tools and teaching products.

Faculties:

Science and Engineering

Lead Academics:

Prof Michael Brear, Mr Andrew Reeves, Prof Rob Evans and Prof Rob Hyndman

Partners:

Monash University

The Centre will target specific challenges Victoria faces in meeting decarbonisation targets, and will make particular use of the advantages Victoria has such as the combination of Advanced Metering Infrastructure (AMI) with a competitive retail energy market.

The proposed Centre has three key goals, these are to:

- Undertake independent and evidence-based analysis on the transformation of our electricity system
- Develop and commercialise new energy technologies and services
- Educate 'new' industry professionals

The Centre plans to undertake independent and evidence-based analysis across three streams. The first stream is system modeling that will focus on the likely full costs of integrating renewables and other technologies into the Australian National Electricity Market through using large-scale computation. The second stream

involves demand forecasting, with emphasis on producing more robust forecasts of energy demands. The final stream is policy oriented with a focus on producing integrated analysis of network performance and demand forecasting, in order to support policy reform. This stream would be realised through quantifying the likely benefits and costs of tariff reform.

The Centre also plans to run a community energy and education program. The community energy program will involve the Centre developing a hybrid power plant for distributed power generation that will be demonstrated at a Victorian school. The Centre aims to develop this technology to bring it to commercialisation. The education program will involve the commencement of a 'Post-graduate Diploma of Energy Systems'. The Diploma will have strong links with the Masters of Energy Systems though will be targeted at full-time working professionals with significant relevant experience.



Projects in Development

BIO-MINING OF RARE EARTH ELEMENTS

The expansion of the renewable energy sector has meant that rare earth elements are in high demand. Finding sustainable ways to extract them is a challenge geomicrobiologists are ready to undertake.

Faculties:

Science

Lead Academics:

John Moreau

Wind turbines, photovoltaics, and electric cars are just a few green technologies that are dependent on the supply of rare earth elements (REEs). Therefore, as the sustainable energy sector grows in an effort to mitigate the effects of climate change, so does the need for rare earth elements.

In order to meet the increasing demand for REEs Australia is encouraged to mine domestically and this makes the need for cheap, environmentally sustainable ways to extract REE's apparent. One way REE's can be extracted sustainably is through bioleaching. Bioleaching is a way in which bacteria are used to dissolve metals in place of using chemical solutions.

Phosphate solubilising microorganisms (PSMs) are of particular interest to REE-bioleaching research due to their ability to co-extract agriculturally useful phosphorus and REEs from phosphate minerals like apatite. Recent studies point to a gap in our understanding of how phosphorus sorbing materials (PSMs) solubilise phosphorus, and between the expression of genes encoding for phosphate solubilizing

enzymes and the actual soluble extracellular molecules attacking phosphate mineral surfaces. We also do not understand the potential inhibitory feedbacks of REE co-extraction on microbial growth and activity.

This research project will conduct experiments on the co-extraction of REEs and phosphates from phosphate minerals by pure and mixed cultures of microorganisms under varying biogeochemical conditions. By identifying novel bioleaching mechanisms and compounds, we will produce new knowledge to help increase REE recovery, and develop a viable and competitive bioleaching process. This project will help develop University capacity in bioleaching research and further Australia's ability to serve as a leader in extracting REE's.



Our People

CAPACITY BUILDING THROUGH EARLY CAREER RESEARCHERS

Supporting early career researchers is a central part of our growth. The Institute has a strong belief that in fostering the ambitious talent of early career researchers we can help these researchers become future thought leaders in energy research. To this end, the Institute provides partial support for academic positions relating to energy research across a number of faculties. Generally, this is done on matching support from host faculties and departments. Here are some of their stories.

SARA BICE



Sara is Director, Research Translation at the Melbourne School of Government

Dr Sara Bice has been named an inaugural Westpac Bicentennial Foundation Research Fellow, one of only four in Australia. The competitive research fellowship, valued at \$474,000, will support her ongoing work into the social and community aspects of underground resources management and policy-making, advancing her ongoing involvement in the Sedimentary Basin Management Initiative.

In 2015, Sara continued her work with Professors Fiona Haines and Helen Sullivan on a 'social licence to operate' for coal seam gas in Australia. The researchers are undertaking fieldwork in 2016, completing an in-depth case study of recent experiences of boom and bust in the Australian CSG industry. With Professor Fiona Haines and Professor Peter Cook, Sara gave advice to the Victorian Auditor General's audit of unconventional gas.

Throughout the year, Sara's work was profiled in a variety of invited keynotes, public lectures, via national and international media, including one of the MEI and Grattan Institutes' Energy Futures Seminars, ATSE/ACOLA First International Conference on Unconventional Gas which also featured the MEI's Prof. Mike Sandiford on a world-leading panel of seismicity experts. Sara also represented the social science perspective on unconventional gas at a related UNSW

public forum, facilitated by the ABC's Michael Brissenden.

In May 2015, Sara was named Director, Research Translation for Melbourne School of Government. Through this role she is leading a two-year, university-wide research program to inform innovative ways to enhance research outcomes and to ensure that the best research reaches wider audiences for social and policy impact. Her work with MEI and the SBMI will be a major focus for research translation.

She continues to produce high quality research publications. Her work with Dr Kieren Moffat, CSIRO was awarded best article, Impact Assessment and Project Appraisal journal at the 2015 International Association for Impact Assessment Conference, and she also published work on corporate social performance in the resources industry in the FT Top-45 journal Journal of Business Ethics. Her book, Responsible Mining: A framework for the 21st century mining industry is due to be published by Routledge in June. Sara looks forward to an exciting and productive year with her MEI colleagues and is grateful for their ongoing collegiality, enthusiasm and support.

Our People

RENAUD COLOUMB



Renaud is a Lecturer in the Faculty of Business and Economics

Renaud's primary fields are environmental economics and energy economics. His work focuses on carbon taxation, fossil-fuels extraction and the perception of extreme events.

In a paper entitled "The Grey Paradox: How fossil-fuels owners can benefit from carbon taxation" and jointly written with Fanny Henriet (PSE), he studies the distributional impacts of optimal carbon taxation on fossil-fuels owners. This paper shows that optimal carbon taxation can increase the profits of owners of a carbon-emitting exhaustible resource. Such phenomenon contrasts with claims from fossil-fuels owners –especially from OPEC member countries– that carbon taxation will undermine their profits.

In a very recent project, he analyses changes in nuclear-risk perception following the Fukushima nuclear

accident of March 2011. The empirical analysis shows a persistent price malus of about 3.5% in response to the Fukushima accident for properties close to nuclear plants.

Prior joining the Department of Economics at Melbourne University, Renaud worked as a researcher at the London School of Economics, Grantham Research Institute on Climate Change and the Environment, and at Ecole Centrale Paris, from October 2013 until September 2015. He holds a PhD and a master degree in Economics from Paris School of Economics and a master degree in International relations from Sciences Po Paris.

COLIN SCHOLES



Colin is a Senior Lecturer in the Department of Chemical and Biomolecular Engineering

Colin has extensive experience in membrane separation, with a strong focus on developing membranes for energy systems. Dr Scholes research encompasses novel polymer design development for more efficient membranes, fundamental modelling of mass transfer through membranes, membrane configuration design and hybrid membrane technologies. In particular, Dr Scholes has researched membranes for efficient CO₂ separation from a range of industries, including both gas separation and membrane contactor technologies. Dr Scholes was also the lead researcher on membrane pilot plants for both post-combustion and pre-combustion carbon capture, highlighting his research's industry potential. Dr Scholes research is world recognised and been

supported through prestigious Fulbright (American Fulbright Commission 2009), Victorian (Victorian Government 2012) and Endeavour (Australian Government 2014) fellowships. Research highlights for 2015 were the development of non-porous membrane contactors to reduce the energy duty of traditional solvent absorption for CO₂ capture.

DIMITRI LAFLEUR

Dimitri Lafleur explores the coal to gas transition and impact that fugitive gas emissions can have on the climate.



Dimitri is a PhD Candidate at the Australian-German Climate and Energy College

The main driver of the increase in greenhouse gases is human-induced (anthropogenic) emissions that result from burning fossil fuels. The Paris Agreement, as proposed by the global leaders in Paris in December 2015, stipulates that the global response to climate change includes

“holding the global average temperature to well below 2°C above pre-industrial levels and to pursue efforts to limit the temperatures increase to 1.5°C above pre-industrial levels.”

Achieving this response requires a reduction of greenhouse gases emissions, particularly carbon dioxide and methane. This means that the next 20 to 30 years are critical in order to adhere to the Paris agreement, as the planet saw the halfway mark to 2°C surpassed in 2015.

The human induced anthropogenic greenhouse emissions make a change in energy system a necessity. In order to move away from fossil fuels while maintaining sustainable economic growth, a switch to cleaner fuels is seen as a plausible scenario. Natural gas is seen as the transition fuel to make this transition possible. It is seen as the cleaner fuel, as it emits only 60% of CO₂ emissions compared to coal when combusted, a process that is required to generate electricity or generate heat. The growth in natural gas demand will come from unconventional gas.

There is however mounting evidence, particularly from the United States, but also from Australia, that CH₄ emissions from unconventional gas extraction and transportation are significantly higher than estimated and reported. The fact that CH₄ has a global warming potential that is 86 times (IPCC, 2013) that of CO₂ on a 20 year timeframe, and the next 20 to 30 years are critical to stay below 2°C, understanding the true emissions of gas developments is crucial in order to transition to a renewable energy system, without

undermining the efforts to avoid dangerous climate change. While the US studies concentrate on shale gas, the Australian unconventional gas projects are coal seam gas (CSG) developments. What sets CSG apart from other unconventional gas developments is primarily the fact that gas is extracted from coals rather than siliciclastic or carbonate reservoirs. The static and dynamic behaviour of coal is vastly different from other sedimentary rocks. One of the consequences is that CSG can only be produced after coals are depressurised (dewatered), in order to extract the gas.

Dimitri's PhD focusses on the gas transition and the potential effects of its fugitive emissions on the climate. One part is investigating the role fugitive emissions from coal seam gas could play. In September 2015, a twelve-day fieldwork campaign in Queensland Condamine area allowed Dimitri to acquire atmospheric methane concentrations and methane fluxes from soils, particularly in areas away from existing coal seam gas wells, to test the hypothesis whether existing faults in the subsurface could be a conduit for methane to leak to the surface. The atmospheric concentrations were recorded by spectrometers at three tower sites some fifteen kilometres apart. They are used to model the most likely sources in the area given the weather pattern. The soil fluxes are measured using soil chambers in order to understand the flux through the soils. They are backed up by lab soil measurements in order to understand how soils and their bacterial communities are behaving in their natural environment and at higher methane concentrations.

This will contribute to the understanding how methane migrates in coals, during production and thereafter. It will also increase understanding how much of a transition gas will play in the world's endeavour to stay well below 2°C.

Public Engagement

In 2015, the Institute continued to bring together industry, government and academia around critical energy research issues through our Energy Futures Seminar Series. The year saw our engagement portfolio grow through hosting seminars with new partners including The Wheeler Centre.

GRATTAN
Institute



The Wheeler Centre
Books Writing Ideas

Run in partnership with policy think-tank Grattan Institute, the Energy Futures Seminar Series presents a range of views on the immediate and long-term impacts of changes in energy policy and the development of novel energy technology solutions.

In 2015, the Energy Futures Seminars, were sold-out throughout the year exploring topics including the future of Australian energy exports in a carbon-constrained world, the impact of the rise of distributed generation and the consequences for consumers and the electricity sector, renewable energy and its ability to meet 'baseload' power and issues surrounding climate change after the Paris conference.

In October, Melbourne Research Institutes, co-hosted an event with The Wheeler Centre, "Is Proof Overrated?" The Institute was delighted to work with distinguished speakers including Professor Peter Doherty, Associate Professor Megan Munsie, Dr Ranjana Srivastava, Professor Kate Auty, and Dr Sara Bice to explore the role

of research-based evidence on the choices we make about everything from energy technologies, social equity, and environmental policies to our use of medical breakthroughs and new communication technologies.

The Institute also hosted a public seminar with the Hon Lily D'Ambrosio, Minister for Energy and Resources, exploring the opportunities and challenges in navigating a cleaner energy future for Victoria. This seminar was the largest of its kind demonstrating the important role the Institute plays in engaging the public in critical energy and policy issues.

The seminars have attracted the attention of audiences of 400-700, with a growing online audience via the seminar web-stream. In 2015, the live-web stream and follow up media coverage of the seminars allowed national and international audiences to engage with the seminars.



Energy Futures Seminar Series 2015

What is the future of Australian energy exports in a carbon constrained world? - 5 March 2015

Tania Constable	Chief Executive Officer, CO2CRC
Keith Lovegrove	Senior Consultant in Solar Thermal, IT Power Group
Fiona Wild	Vice President Environment and Climate Change, BHP Billiton
Rob Clinch	Associate, ARUP
Maxine McKew	Vice Chancellor's Fellow, University of Melbourne

Is it time to leave the grid? The rise of distributed generation and the consequences for consumers and the electricity sector - 28 May 2015

David Blowers	Energy Fellow, Grattan Institute
Michelle Groves	Chief Executive Officer, Australian Energy Regulator
Kiera Poustie	Policy Analysis Manager, United Energy
Tristan Edis	Editor, Climate Spectator

Can renewable energy meet 'baseload' power? - 19 August 2015

Roger Dargaville	Deputy Director, Melbourne Energy Institute
Andrew Blakers	Director, Centre for Sustainable Energy Systems, Australian National University
Nicola Falcon	Group Manager Planning, Australian Energy Market Operator
Del Irani	Journalist, ABC News Breakfast

Climate Change: What happens after the Paris Conference? - 13 October 2015

Tony Wood	Energy Program Director, Grattan Institute
Anthea Harris	Lead Deputy Secretary, Strategy and Planning, Department of Economic Development, Jobs, Transport and Resources, State Government of Victorian
David Karoly	Professor of Atmospheric Science, School of Earth Sciences, University of Melbourne
Tom Arup	Environment Editor, The Age

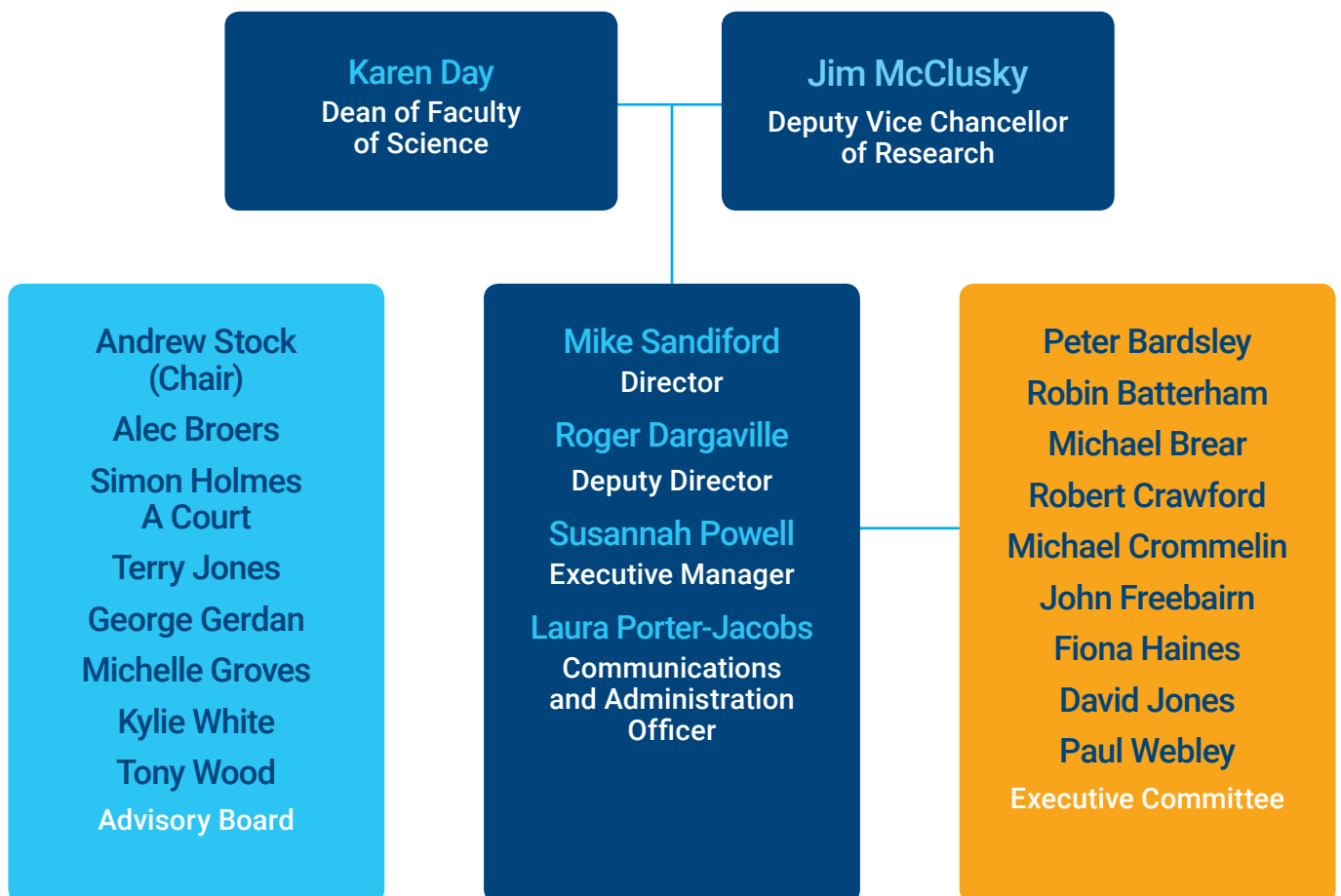


Governance

The Institute reports to the Deputy Vice Chancellor of Research, Professor Jim McClusky, for research matters and the Faculty of Science Dean, Professor Karen Day, for operational matters.

The Director and Executive Committee govern the Institute and the Advisory Board provides strategic advice. The Executive Committee is made up of senior academics from the Faculties of Engineering, Law, Arts, Science, Business and Economics, and Architecture, Building and Planning.

A small team of professional staff support the Director in the administration of Institute activities.



New Funding Initiatives

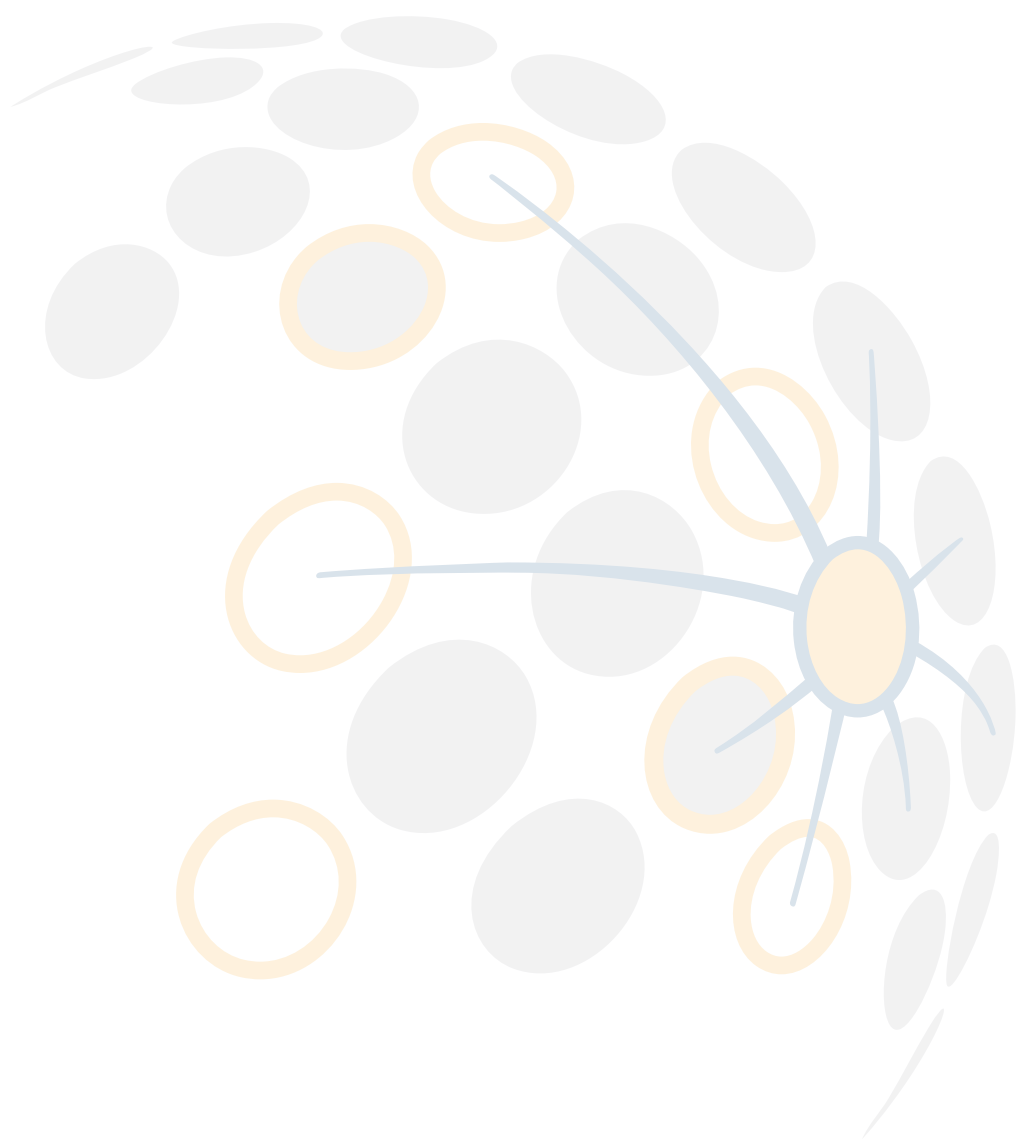
Confirmed new funding for Institute led and supported activities in 2015

Funding Source	Name	CI/proponent	Faculty	Funding Period	Total (\$k)
National Collaborative Research Infrastructure Strategy	Basin GENESIS Industry Transformation Research Hub	Prof Louis Moresi	SCI/ENG	2015	600
Westpac Bicentennial Foundation	Sedimentary Basin Management Initiative	Dr Sara Bice	ARTS	2015	474
C02CRC	Carbon Capture and Storage	Prof Ralf Haese	SCI	2015	555
Australian Renewable Energy Agency	Renewable Energy Integration	Dr Roger Dargaville	SCI/ENG	2015	148
Community Donations	Australian Gas Demand	Mr Tim Forcey	SCI	2015	10
The Australia Institute	Australian Gas Demand	Mr Tim Forcey	SCI	2015	25
Total (\$k)					1,807
Multiplier					1.85

Expenditure

Melbourne Energy Institute 2015 Budget

Operations	
Salaries	\$332,000
Administration and general expenses	\$44,000
Events and communications	\$27,000
Subtotal	\$403,000
Research	
Capability	\$365,000
Project Seed Funding	\$47,000
Partnership development seed funding	\$110,000
Director's discretionary	\$50,000
Subtotal	\$572,000
Total	\$975,000



FOR MORE INFORMATION VISIT OUR
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Executive Manager

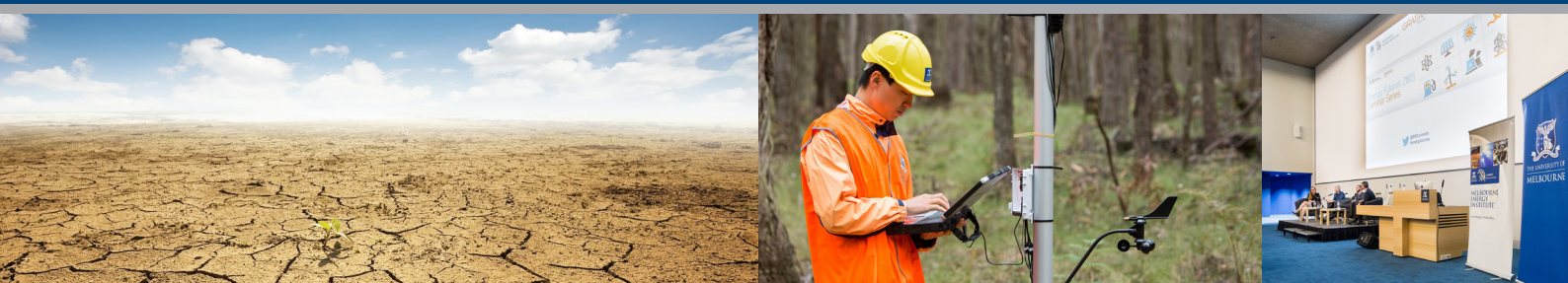
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